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Does the femoral head/neck contour in the skeletally mature change over time?

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ABSTRACT

The purpose of this study was to determine whether anterior/anterolateral femoral head/neck contour of the hip is static or dynamic over time within the context of the cam deformity. From a previously published cohort of 200 asymptomatic patients who had a magnetic resonance imaging (MRI) of their hips, 23 patients were randomly selected: 10 with a cam lesion and 13 with no evidence of a cam lesion in either hip. There were 7 females and 16 males with a mean age of 37.5 years (range 30–56 years). A repeat MRI or computed tomography scan was performed. Femoral head/neck contour was assessed with alpha angle measurements at the 3 and 1:30 positions. At mean time of 5.3 years (range 2.5–7.2 years) between the two time points, the mean alpha angle for the entire cohort was not significantly different with alpha angle of 43.4°/53.7° (3:00/1:30 positions) at first visit and 46.1°/54.2° (3:00/1:30 positions) at second visit, respectively. Subdividing the cohort into cam negative and cam positive groups, there are no clinically relevant differences (i.e. <5°) between the two alpha angle measurements. Inter-observer reliability had an intra-class coefficient at 0.96 (95% CI: 0.94–0.97). Neither group of patients demonstrated clinically relevant change in the alpha angle. Consequently, screening at time of skeletal of maturity would be an efficient means of identifying individuals for a possible cam deformity.

INTRODUCTION

Ganz et al. [1] described femoroacetabular impingement (FAI) of the hip where there is pathological contact between the femur and acetabulum with two basic mechanisms: cam and pincer. Cam-type impingement results from a contour abnormality of the femoral head–neck junction leading to abnormal contact with the acetabulum, causing hip pain, labral tears, cartilage delamination and potentially osteoarthritis later in life [2–8]. The presence and severity of the cam deformity has been associated with significant acetabular cartilage damage [9].

The prevalence of the cam deformity has been shown to be 10–15% in the normal population and up to 94% in patients with hip pain [10, 11]. However, little is known as to the natural history of the cam deformity, specifically as to whether it changes over time. More recently, some authors have proposed a developmental origin of the deformity by establishing a link between high activity levels during early adolescence influencing proximal femoral physeal growth leading to a higher prevalence of cam deformities FAI [12–16]. Another explanation could be reactive bone formation secondary to high activity or as part of the osteoarthritic process which would mean that the cam deformity could potentially evolve and change over time after the individual has reached skeletal maturity [17].

Understanding if the cam deformity remains static once it has formed, has important implications in regards to considering the possible benefits of establishing screening protocols. Therefore the purpose of this study is to determine whether the femoral head/neck contour changes over time in a cohort of skeletally mature individuals.

MATERIALS AND METHODS

This study was approved by our institutional review board, and all participants provided informed consent. This study is an extension of our study entitled *Prevalence of Cam-Type Femoroacetabular Impingement Morphology in Asymptomatic Volunteers* by Hack et al. in 2010 [10] in which 200 asymptomatic volunteers were assessed for the presence of cam-type morphology (an alpha angle > 50.5°). The SD of alpha angle measurements from that study ranged from 7.0° to 8.1°. A more conservative criterion of 5° was set as clinically relevant difference for detecting changes in morphology. *A priori* power analysis using G*Power (http://www.gpower.hhu.de/en.html) revealed that, in order to detect a 5° difference in alpha angle between the two time points in the same individuals with 80% power, a sample size of 23 patients was required (alpha = 0.05. $d = 0.625$, two-tailed). These were randomly selected from the previous cohorts of 200 volunteers. Ten participants had a confirmed cam lesion (alpha > 50.5°) (Cam Positive Group) at the initial evaluation and the remaining 13 patients were in the normative group with alpha angles <50.5° (Cam Negative Group). There were 7 females and 16 males with a mean age of 37. 5 years (range 30–56 years). The patients were re-evaluated by magnetic resonance imaging (MRI) or computed tomography (CT) scan (11 MRI and 12 CT).

The patient set up and positioning used for MRI and CT image acquisition is identical at our centre. Patients are placed supine, straight and thus parallel to the long axis of the imaging table. Both feet are held together in neutral position with fabric ties/straps. There are no wedges or pillows placed under the hips or the lower extremities. The field of imaging is consistent between patients and visits by using standard anatomic landmarks which ensure consistent coverage of the osseous structures.

The MRI examinations were carried out on a 1.5-T scanner (Symphony Quantum; Siemens, Erlangen, Germany) with a phased-array surface coil placed anteriorly over the pelvis and with spine phased-array coils placed posteriorly. The MRI sequence was a three-dimensional isotropic, T1-weighted spoiled gradient echo (MP-RAGE/TurboFLASH [magnetization-prepared rapid acquired gradient-echo sequence/fast low-angle shot]; 38.4-cm field of view; 1-mm slice thickness; 384×384 matrix; 1250-ms repetition time; 2.44-ms echo time; 15° flip angle and one average). The CT scans were performed on one of two scanners (Aquilion, Toshiba, Tokyo, Japan; or Discovery CT750, General Electric, Milwaukee, WI) covering from the iliac crest to the lesser trochanter. Scan parameters were 120 kVp, 200 mAs, slice thickness 0.5–0.625 mm and a 512×512 matrix resulting in an in-plane resolution of 0.72–0.98 mm, depending on the size of the subject. CT images were acquired in the axial plane and reconstructed using a bone algorithm.

Multiplanar reformation for either the MRI or CT images, for each hip, was performed to generate 2-mm-thick oblique axial and oblique sagittal plane images, parallel and perpendicular to, respectively, the long axis of the femoral neck. The latter plane was used to prescribe the radial multiplanar reformation, with use of the center of the femoral neck as the axis of rotation, with 2-mm-thick images generated at 15° intervals. Acquisition and multiplanar reformation images were sent to PACS (picture archiving and communication system) software (Horizon Rad Station 3.3; McKesson, San Francisco, CA) for review.

Alpha angles were measured with use of the previously published method by Notzli et al. [18]. A best-fit circle was drawn around the perimeter of the femoral head. The first arm of the angle was the long axis of the femoral neck, defined as a line drawn between the center of the femoral neck at its narrowest point and the center of the circle. The second arm of the angle was drawn from the center of the circle, anteriorly to the point where the femoral head extended beyond the margin of the circle (Fig. 1). Alpha angles were measured for these repeat scans by a musculoskeletal radiologist and an orthopaedic surgeon.

In order to determine the comparability of the two different imaging modalities, 12 patients (24 hips) underwent both CT and MRI within 6 months at the time of original evaluation.

The alpha angle was measured at two locations along the femoral head–neck junction (3 o'clock anterior and 1:30 anterosuperior) for each hip. The findings were then compared with the original MRI readings to identify any difference in alpha angle using paired *t*-tests, with significance set as $P < 0.05$. An inter-observer reliability analysis was also performed.

RESULTS

At a mean time of 5.3 years (range 2.5–7.2 years) between the two imaging sessions, the mean alpha angle for the entire cohort was not significantly different between the initial and subsequent follow-up time points with values (3:00/1:30 positions) of 43.4°/53.7° and 46.1°/54.2°, respectively. Subdividing the cohort into cam negative and cam positive groups, again there was clinically relevant change in alpha angle between the two imaging time points at either the 3:00 or 1:30 positions (Table I). The inter-observer reliability was high, with intra-class coefficient at 0.96 (95% CI: 0.94–0.97).

MRI versus CT

The mean alpha angle values at the 3:00 position were 45.6° for MRI (SD 8.5), compared with 49.4° for CT (SD 9.8).

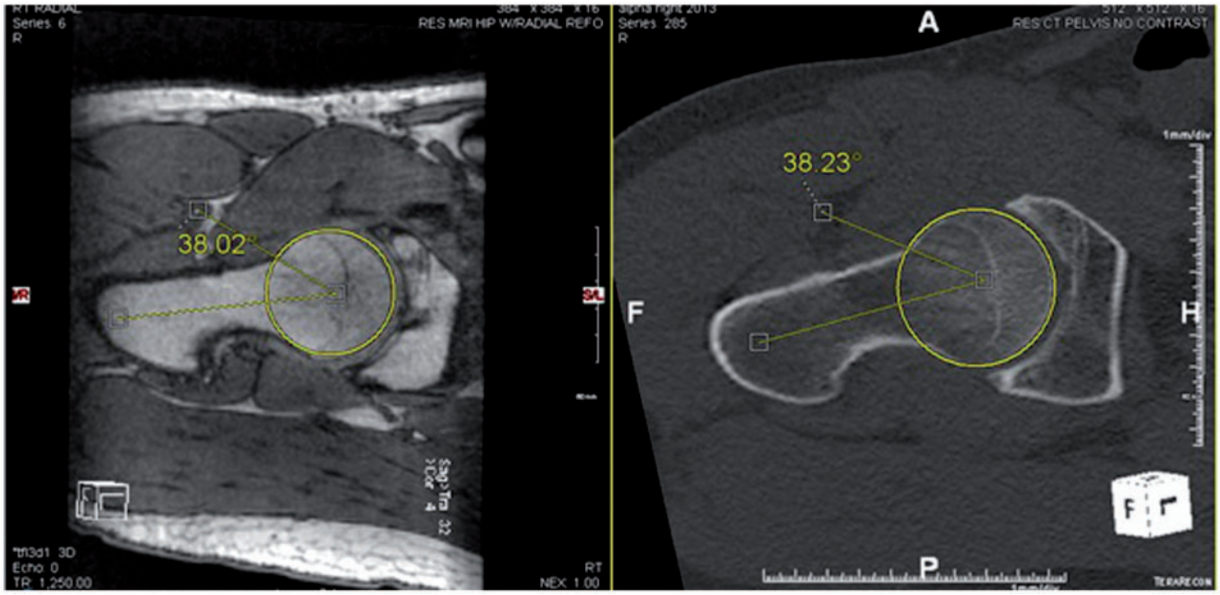

Fig. 1. MRI and CT of the same hip at different time points demonstrating measurement of the alpha angle at the 3 o'clock position.

Table I. ***Alpha angle measurements at 1:30 and 3:00 at two different time points***

Groups	*1st AA*	*2nd AA*	P *values*
CAM positive			
3:00	48.7 (7.6)	51.7 (7.7)	0.040
1:30	62.5 (9.2)	61.5 (9.1)	0.593
CAM negative			
3:00	36.9 (6.7)	39.2 (6.9)	0.123
1:30	47.4 (7.0)	49.0 (9.6)	0.261

Mean and SDs are indicated.

The mean values at the 1:30 position were 53.3° (SD 8.0) for MRI, compared with 56.4° (SD 10.1) for CT.

DISCUSSION

Femoroacetabular impingement has been proposed as the principal pathomechanism leading to degenerative arthritis of the hip where bony deformities of the proximal femur (i.e. cam) and acetabulum (i.e. pincer) lead to damage to the labral–chondral junction and eventual failure of the hip joint [6, 19]. However, our current understanding of who is at risk of developing arthritis with FAI is still evolving [20]. Recent work by Agricola has shown that in individuals with a cam deformity severity of deformity as well as limited internal rotation and activity level are significant risk factors for arthritis [21]. In addition, the severity of the cam deformity has been strongly correlated with presence and new onset of hip pain [15, 22, 23]. However, other factors such as a change in patient activity level or in the severity of the cam deformity over time may also play a role in the new onset of hip pain over time. The question as to whether the severity of cam deformity continues to change over time or remains static after skeletal maturity is a critical one as timing of surgical intervention to minimize extent of articular damage could be impossible to determine.

In our study, looking at a prospective cohort of asymptomatic individuals at two different time points we found no significant change in alpha angle measurements at both the 3:00 and 1:30 positions over 5.1-year period. This was true for both the individuals with a cam deformity at the time of initial assessment as well as those with a normal head/neck contour. These findings are consistent with those looking at femoral head/neck remodelling after surgical correction [24, 25]. Both Nassif et al. [24] and Neumann et al. [25] found no recurrence of the cam deformity after surgical correction at a mean of 2 years of follow-up in 135 and 45 patients, respectively. Having said that, further follow-up maybe required to determine any longer term changes.

Early recognition of FAI may be important to provide the opportunity for intervention before the development of advanced articular cartilage disease. Consequently, identification of individuals at risk of developing hip pain secondary to the cam deformity could be done as early as completion of skeletal development. This is especially for high level athletes where a high prevalence of cam deformity has been reported. Sports like soccer, hockey, football that involve repetitive hip flexion activities may also exacerbate symptoms in the 'at-risk' hip [12, 14, 26–30]. Recent work by Siebenrock as well as others, have also shown that repetitive stress to the proximal physis during intense sporting activities alters the proximal femoral physis's growth leading to formation of the cam deformity [12, 13, 29, 31]. More specifically, the presence of the cam deformity was significantly associated with greater activity level encountered during basketball and ice hockey. In a more recent paper, Carsen et al. [13] also showed that the higher activity associated with the cam deformity is not necessarily restricted to a particular sport where in their cross-sectional cohort analysis no particular sport was targeted. These findings in the paediatric/young adolescent group are consistent with the prevalence of the cam deformity in the adult population. Agricola and colleagues reported on the prevalence of cam-type morphology in high level soccer players [32]. They demonstrated a significantly higher prevalence of either prominent cam morphology or head–neck flattening in 56% of soccer players compared with 18%, in a normalized control population. Similarly, Kapron et al. [33] reported a cam prevalence of 57% in male collegiate football players and Siebenrock et al. [34] reported a 56% prevalence in elite ice hockey players. Our results and literature further support the hypothesis of Murray that the cam deformity forms during the period of skeletal maturation [35].

Our study has some limitations. Although a change of 5° in alpha angle was determined clinically relevant, it is unknown if a smaller change could alter the risk of developing cartilage hip damage. However, changes of 5° or less could simply represent measurement error hence a value >5° would most likely be a true change. Another limitation is the use of CT in some patients for the repeat measurement. Nonetheless, when we compared CT and MRI in our patient cohort the difference was <5°. Also, making a similar comparison of CT versus MRI looking at slipped capital femoral epiphysis morphology, Monazzam et al. [36] found both techniques to be comparable. Finally, the use of the alpha angle to assess the cam deformity may in of itself be insensitive due to its two dimensional assessment. To minimize this, the alpha was measured at both the 3 and 130 positions which we believe should be sufficient to detect change. Future work using three-dimensional surface morphology could prove to more accurate to assess the cam deformity which may prove more accurate. The mean follow-up is still relatively short at 5.3 years leaving the possibility of further change later on. However, both by Nassif et al. [24] and Neumann et al. [25] looking at femoral head/neck remodeling after cam deformity correction found no recurrence of the deformity in 135 patients and 45 patients, respectively, at 2 years of follow-up.

In another study, it was reported that 4 of 19 patients had osteophyte formation after surgery, and all four also had preoperative joint space narrowing, which most likely reflects progression of arthritis then reformation of the cam lesion [31]. To our knowledge this is the first study that tried to determine if the cam deformity is static or dynamic. Neither the previously identified patients with a cam-type lesion, nor the control group without a cam lesion demonstrated any identifiable change in alpha angle over approximately a 5.3-year time period. Consequently, screening at time of skeletal of maturity would be an efficient means of identifying individuals with this deformity.

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Each author certifies that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest and patent/licensing arrangements) that might pose a conflict of interest in connection with the submitted article.

ETHICAL REVIEW COMMITTEE STATEMENT

Each author certifies that his or her institution approved the human protocol for this investigation, and that all investigations were conducted in conformity with ethical principles of research.

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