Cam Shape in Male and Female Patients with Femoroacetabular Impingement (FAI)

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Mandatory Disclosures

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- I have no financial relationships to disclose.

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- Dr Michael A Bowes is an employee of Imorphics Ltd, a wholly owned subsidiary of Stryker Corp.

Introduction

- Arthroscopic surgery is frequently used to correct the cam-type anatomical deformity associated with FAI. [1, 2]
- Morphology of FAI is largely understood, however, geometric differences between male and female cam lesions are less well reported. [3, 4]
- In this study, volumetric CT images were interpreted using femoral active appearance models, enabling the geometrical properties to be compared using statistical shape models. [5]

The aim was to compare the geometry of cam lesions in male and female patients, with a clinical diagnosis of FAI, using 3D imaging and statistical shape models.

Research Data

- Symptomatic patients (n=41 male; n=26 female), mean age 36 years (21-63) and 37 years (23-51) respectively, were recruited to the study.[a]

Inclusion Criteria

- ✓ able to give informed, written consent
- ✓ aged 18 years or over and skeletally mature
- ✓ clinical diagnosis of cam FAI
- ✓ pre-operative CT scans readily available

Exclusion Criteria

- × did not fulfil the inclusion criteria
- × had undergone surgery in the affected hip prior to the CT
- × had an existing hip condition that would compromise their participation in the study

[a] Study approved by University of Leeds faculty research ethics committee (Ref: MEEC 11-044)

Method – (1) Creation of Manual Bone Surfaces

Analysis of CT Scans → **3D Wire Models** → **3D Surface Models**

Fig. 1

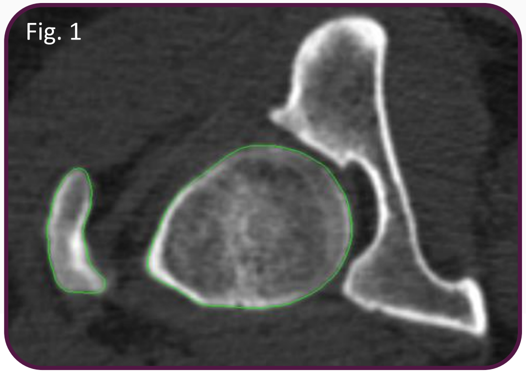


Fig. 2

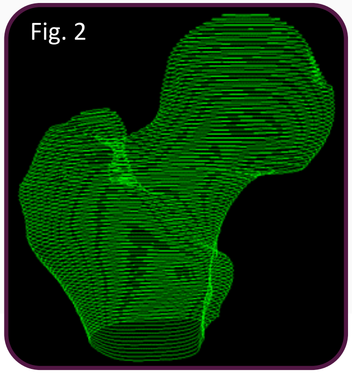
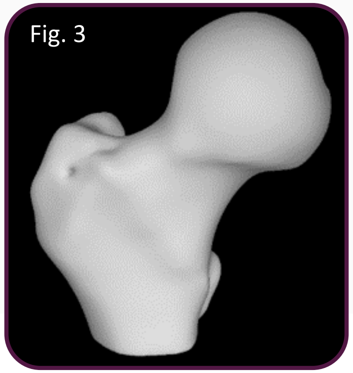


Fig. 3



CT images of each hip in the study were viewed and segmented (Fig. 1) using EndPoint software (ver. 1.2, Imorphics Ltd, Manchester, UK).

The segmentation process involved drawing a line around the boundary of the femur on each CT slice.

Segmented slices were extracted from the scan automatically by EndPoint, and sequentially stacked.

This generated a set of contours for each slice of the CT scan, which could be viewed as a wire model to check its accuracy (Fig. 2).

A 3D surface (Fig. 3) for each femur was then generated from the stack of contours.

This was done using a marching-cubes algorithm, followed by quadratic smoothing of the resultant surfaces.

Method – (2) Creation of Active Appearance Bone Surfaces

The bone surfaces were automatically segmented from the CT images using active appearance models (AAMs), built from an independent training set [6].

Femurs were fitted with a dense set of correspondence points (>110,000 points), called landmarks, and each point was separated by ~0.5 mm.

At this stage, each femoral bone surface existed in two forms:
(1) The manual bone surface (2) The AAM bone surface

Correspondence points from the AAM surface were transferred onto the manual surface by projecting normals from each correspondence point to intersect with the manual surface.

This process resulted in an accurately segmented femoral bone surface, fitted with a set of anatomical landmarks. These were used for comparisons across the population and for alignment and rotation of the bones.

3D Statistical Shape Models (SSMs) were generated from the male and female femoral surfaces, enabling the two groups to be compared.

Results - Sammon Map

- Femoral shape distributions were explored using Sammon mapping.
  - This reduced the dimensionality of the 3D data to 2D space, whilst preserving the geometric relationships between data points. [7]
- Separation of male and female 2D shape distributions was observed (Fig. 4), suggesting some gender-related geometric differences.

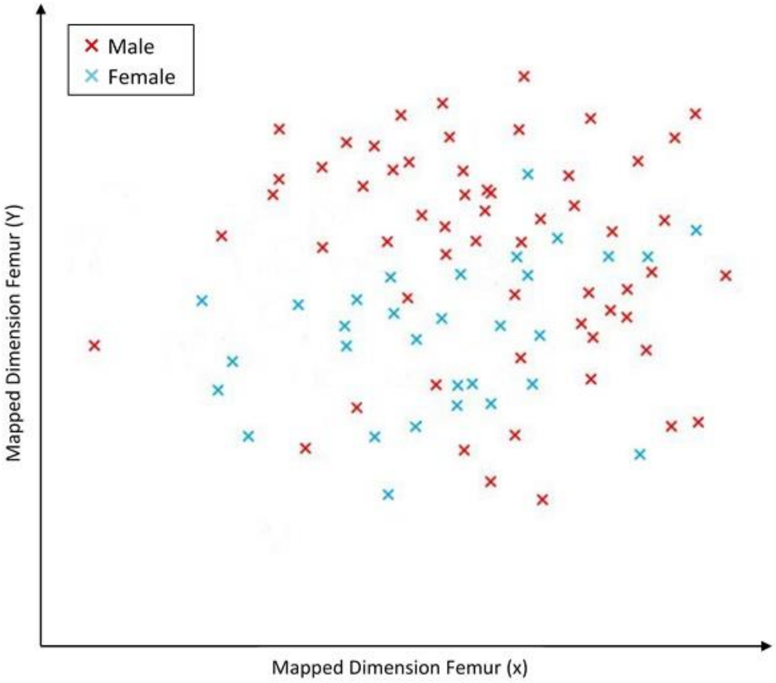


Fig. 4: Sammon map showing the 2D femoral shape distribution of male and female participants.

Results – Statistical Shape Models

- Bony material on the anterior-superior femoral head-neck junction was observed in both groups. This was generally larger in males.
- SSMs showing the extremes of shape (i.e. those points well separated on the Sammon map [Fig. 4]), show a well-defined male cam lesion (Fig. 5a) and a smaller, less well defined female cam lesion (Fig. 5b).
- Cam deformities also appeared to be associated with geometric changes around the posterior aspect of the proximal femur.
- Compared to a group of control patients[b], the greater trochanter and intertrochanteric crest appeared to be parallel to the posterolateral aspect of the head, including the cam (Fig. 5).

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[b] Control group SSMs (created from n=14 male and n=21 female participants) were generated by the same authors using CT scans from patients with no bony hip pathology.

Results – Statistical Shape Models

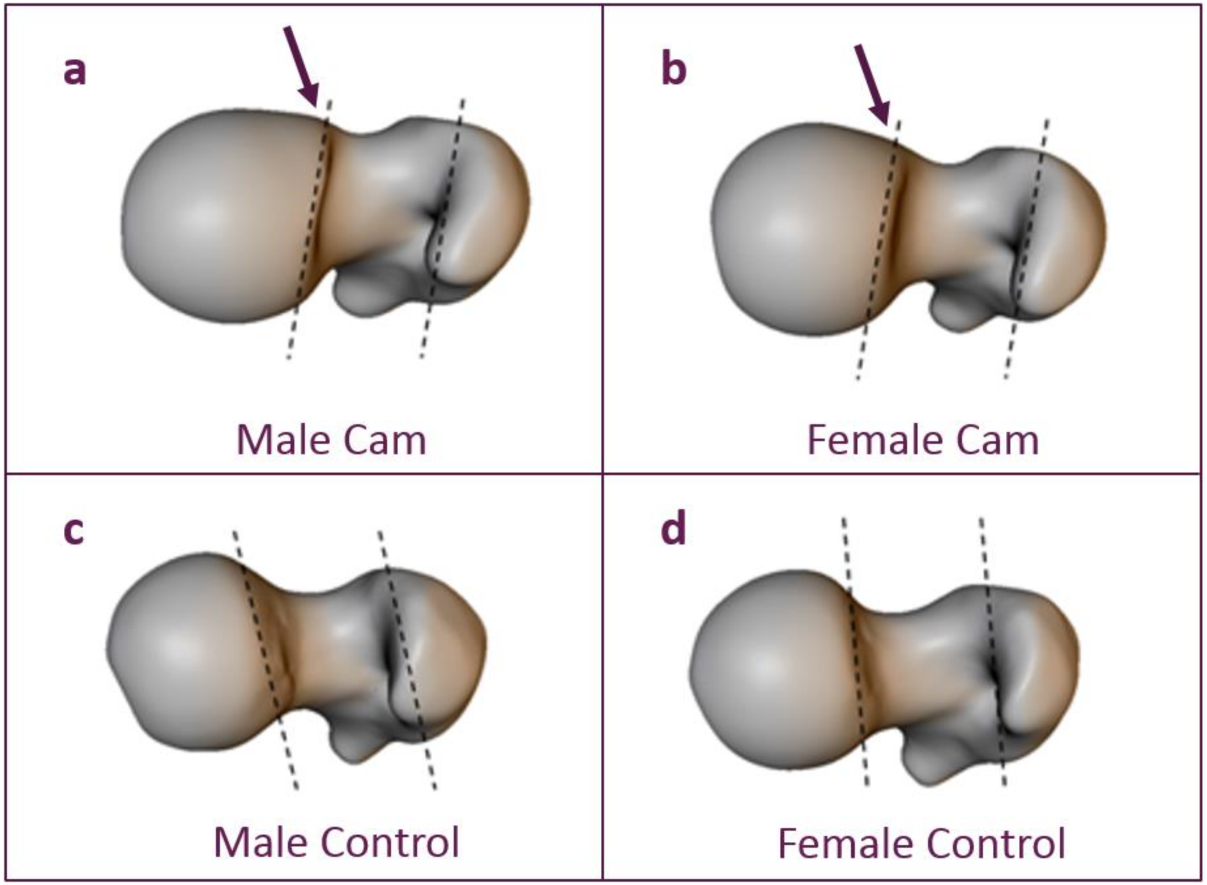

Fig. 5: Statistical shape models showing the extreme (95% CL) versions of the (a) male and (b) female cam lesions, with arrows indicating the location of the cam. Dashed lines show the orientation of the greater trochanter relative to the femoral head/cam.

Figs. 5c and 5d are male and female control group SSMs used to illustrate the geometric differences.

Discussion

- Geometric variations in 3D cam lesion geometry of male and female patients with FAI were compared using SSMs, generated from CT images by combining manual and automatic segmentation methods.
- The aim of this study was met and the results suggest that gender-related geometric differences in cam deformities exist.
- The authors also believe that the associated change in morphology of the greater trochanter is a new finding.
- Future work will include investigating possible underlying causes for any of the reported gender differences, quantifying the volumetric difference between male and female cam lesions, and further investigations relating to trochanter morphology.

Clinical Significance

- The key findings of this study were that:

  a. Cam lesions in the female patients were found to be smaller and more poorly defined when compared to the male cam lesions

  b. There appeared to changes in trochanter morphology associated with the cam lesions

- The authors conclude that that the results of this study relating to cam size have important implications when treating female patients presenting with hip pain, as those with underlying cam pathology may be at greater risk of not being diagnosed and treated.

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