PREDICT NORMAL SHAPE OF FEMUR FOR CAM-TYPE DEFORMITY USING STATISTICAL SHAPE MODEL

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SUMMARY
Cam-effect impingement, which is related to femoral head-neck deformity, is a common cause of hip impingement. Statistical shape modelling technique aims to calculate a mean shape and to extract mathematical descriptions of morphological variations from a set of complex shapes. This technique is used to predict a normal shape for a cam-type femur based on landmarks taken from normal area of this cam-type femur. A statistical shape model (SSM) was constructed from a set of normal femora cut below the lesser trochanter. The cam-type femur was also cut below the lesser trochanter and registered to the common coordinate system of the SSM. Landmarks were taken from those normal areas of the cam-type femur. A new shape fitting the landmark cloud was then constructed by changing the morphological variations from the mean model iteratively until the root mean square (RMS) distance between the resulting shape and the landmark cloud was smaller than 0.05mm. The comparison between the prediction and the original model shows significant differences at the deformity area, with a maximum distance of 5.5mm. This indicates that this type of modelling can be used to provide a normal prediction for bones with deformity.

INTRODUCTION
Cam-effect impingement has been recognised as a common cause of hip impingement [1]. The cam-effect impingement occurs when the femoral head-neck junction has an abnormally large radius resulting in collision between the femur and acetabular rim [2].

Statistical shape modelling is a model-based image analysis technique, which provides a parametric framework for representing variability in a large number of individual complex anatomical shapes [3]. One important application of this technique is to construct a complete surface from a set of sparse landmarks, as reported by Fleute and Lavallée [4] and Yang [5].

METHODS
A set of SSM was constructed using thirty femora with no known pathology. Three dimensional (3D) surface models of these femora were cut below lesser trochanter. They were aligned to a common coordinate system using iterative closest point (ICP) algorithm [6]. Point-to-point correspondences were established using non-rigid registration based on multi-resolution B-spline free form deformation [7]. Principal component analysis was then performed to calculate the mean shape of the dataset and to extract the morphological variations (principal components).

3D surface model of a femur with cam-type deformity was also cut below lesser trochanter and aligned to the common coordinate system of the SSM. Sixty Landmarks were taken randomly from the cam-type femur avoiding the deformity area (Figure 1).

Figure 1: Landmarks taken from the femur with cam-type deformity.

A new shape fitting the landmark cloud was constructed by changing the weight on each principal component from the mean shape iteratively. The deformation procedure was coded by Yang [5] using a linear equation system reported by Rajamani et al [8] to achieve a set of weights that best fit the deformed shape to the landmark cloud. This ‘fitting’ procedure was implemented iteratively until the RMS distance between the resulting shape and the landmark cloud was smaller than a pre-defined threshold (0.05mm in this case).

RESULTS AND DISCUSSION
Figure 2 shows the first two morphological variations extracted from the dataset. The first variation is related to size. The second variation is related to the ratio of length and thickness.
A 3D shape was predicted based on the landmarks shown in Figure 1. The RMS distance between the predicted shape from landmark clouds and the original cam-type femur is 3.4mm. Figure 3 shows a colour mapping of the difference between the prediction and the original shape.

The prediction shape is significantly different from the original shape at the deformity area. The maximum difference between the models at the deformity area is 5.5mm.

This model also shows some mild differences at other areas of the proximal femur, especially the distal part of the model, which requires further work.

CONCLUSIONS
Statistical shape modelling was used to predict a normal shape based on landmarks taken from normal area of a cam-type femur and a SSM constructed from a set of normal femora. The comparison between the prediction and the original model shows a significant difference at the deformity area. This indicates that statistical shape modelling technique has great potential to provide a normal prediction for bones with deformity.

An application of this type of work is to plan surgical intervention in this type of deformity. For example, resurfacing arthroplasty for cam-type deformities is a technically demanding operation, which requires both accuracy and precision [9]. Cobb et al [9] reported that operations with computed tomography-based navigations produced more acceptable precision than conventional instrumentation. The planning and implementation of this kind of surgery might be further optimised and enhanced using information achieved through the technique presented here.

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REFERENCES
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