Novel Shape-Fitting Method Aids in Virtual Surgical Correction Planning for Cam-Type Femoroacetabular Impingement Syndrome

Martina Guidetti, Alex Newhouse¹, Thomas Daniel Alter, Shane Jay Nho², Alejandro Espinoza³, Philip Malloy¹
¹Sports Medicine, ²Midwest Orthopaedics at Rush, ³Sports Medicine, Rush University Medical Center

INTRODUCTION:
Inaccurate characterization of cam type femoroacetabular impingement syndrome (FAIS) morphology, as obtained from the currently available 2D standard methods, precludes timely diagnosis and is the main cause for the high rate of revision arthroscopy for FAIS¹. Recently, new metrics for the three-dimensional (3D) quantification of cam morphology have been developed.² The aim of this study was to determine the accuracy of a new shape-fitting method, which produces a virtual hip arthroscopic plan of cam resection for FAIS, in quantifying cam morphology using only a preoperative MRI scan of the patient hip.

METHODS:
3D bone models were created based on both preoperative and postoperative 1.5T MRI scans obtained from 15 patients with FAIS (Fig.1.1). A new shape-fitting method was applied to the preoperative bone model to reveal the optimal shape virtual model of the proximal femur (Fig.1.1). The shape-fitting method was implemented in different steps that consist in: finding femoral landmarks, selecting the femoral head and neck regions and fitting them with known shapes (such as sphere and convex hulls, respectively), creating a Boolean union of the fitted shapes to create an initial optimal shape template of the proximal femur and then smoothing the surface of the initial template to obtain an optimal shape template of the proximal femur. The Boolean union of the optimal shape template of the proximal femur and the original distal part of the femur forms the optimal shape virtual model. The Boolean subtraction of the optimal shape virtual model from the preoperative reconstructed 3D model gives the virtual plan of the cam resection that was quantified using the metrics of height, surface area and volume.² These last two steps were performed in MeshLab. The metrics were then respectively normalized by the radius, surface area and volume of the sphere fitting the femoral head surface (Fig. 1.2). The actual cam morphology, resected during hip arthroscopy performed by an expert surgeon, was also obtained by subtracting the postoperative from the preoperative 3D model and it was quantified using the same metrics used to quantify the virtual cam resection (Fig.1.2). The accuracy of the new method was evaluated by determining the agreement between the metrics quantifying the virtual cam resection and those measuring the actual cam resection (Fig.1.3).

RESULTS:
Bland Altman analysis revealed a 97.8% average level of agreement between the metrics for actual and virtual cam characterization with 100%, 93% and 100% of the data points falling within the limits of agreement for normalized height, surface area and volume, respectively (Fig.2).

DISCUSSION AND CONCLUSION:
The metrics derived using the shape-fitting method have shown to be accurate when compared to the same metrics quantifying the actual cam resection. The advantage of the shape-fitting method is that it allows to generate equivalent metrics using only the preoperative model, therefore providing a means for surgical planning. Further research is needed to determine the relationship between these metrics for the quantification of cam morphology and current clinical measures such as the radiographic alpha angle, as well as investigation into whether these metrics can predict a patients functional outcomes following surgery. This new shape-fitting method offers an alternative strategy for the non-invasive characterization of cam morphology. Therefore, it has the potential to improve diagnosis and surgical planning for FAIS by reducing the rate of revision surgeries, thereby preventing the progression of FAIS into hip osteoarthritis.