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CORR Insights®: Head-Neck Osteoplasty has Minor Effect on the Strength of an Ovine Cam-FAI Model: In Vitro and Finite Element Analyses

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Where Are We Now?

Osteochondroplasty, performed arthroscopically or as an open procedure, has become the de-facto treatment for adults with hip pain secondary to a radiographic diagnosis of cam-type

femoroacetabular impingement (FAI). One challenging aspect of surgery is properly contouring the cam lesion. Too aggressive of a resection may lead to iatrogenic fracture [2, 8], loss of the normal joint suction seal, and/or loss of congruency. However, too modest of a resection may fail to resolve patient symptoms [9].

A case report of a patient who experienced iatrogenic fracture raised questions regarding the safety of osteochondroplasty [2]. More-recent clinical data helped to mitigate concerns, where the prevalence of iatrogenic fractures was reported at 0.07% [8]. Still, initial fears regarding iatrogenic fracture may have had the unintended consequence of making surgeons, especially those inexperienced in the field of hip preservation,

to err on the side of caution. At present, a much-more-common reason for failed osteochondroplasty is underresection [9]. Guidelines establishing the resection depth necessary to remove the cam lesion, while still leaving sufficient bone stock to support the femoral neck, may help to reduce rates iatrogenic fractures as well as the number of patients who have residual deformities following the index osteochondroplasty.

In the current study, Maquer and colleagues found that resections to the maximal amount tested (9 mm, or ~36% of femoral neck diameter) yielded a femur that withstood forces greater than two times that measured in-vivo in sheep during maximal loading, suggesting that relatively aggressive resections are safe. Their value of 36% of the femoral neck diameter was similar to the 30% resection deemed safe in earlier work [7], but is somewhat at odds with another study that used a composite bone model where it was suggested that any resection of the anterolateral region significantly reduced the strength of the proximal femur [6].

This CORR Insights® is a commentary on the article “Head-Neck Osteoplasty has Minor Effect on the Strength of an Ovine Cam-FAI Model: In Vitro and Finite Element Analyses” by Maquer and colleagues available at: DOI: 10.1007/s11999-016-5024-8.

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Ideally, fracture strength could be assessed in-vitro for human hips that had a history of hip pain and radiographic signs of FAI. Unfortunately, it would be difficult, if not impossible, to acquire cadaver tissue where symptomatic FAI was diagnosed and left untreated prior to death. Patient-specific computer models are potentially advantageous in this regard, as they can incorporate variability in morphology and material properties on a per-individual basis. To support the future use of patient-specific models to predict fracture strength, Maquer and colleagues validated finite element (FE) models of ovine specimens by comparing computer-predicted fracture strength and fracture pattern to that measured and observed in-vitro in the same specimens. Regarding force-to-failure and fracture pattern, the authors found similarities between model and experimental data. Although additional validation work will be necessary, results by Maquer and colleagues suggest that FE models could be used as a preoperative tool to plan resections and evaluate the safety of each.

Where Do We Need To Go?

The ovine model provides an excellent platform to assess the effects of osteochondroplasty. In particular, the cam deformity is controlled

extrinsically, which minimizes morphologic variation as a confounding factor. However, cam lesions found in humans are quite complex, varying in size and anatomic location. In addition, cam FAI patients often present with concomitant deformities to the acetabulum. Computer models incorporate patient-specific anatomy, and thus may yield data that is more clinically relevant than that based on experiments of sheep. The challenge, however, is convincing the clinical and basic-science audiences that models are valid, and that they yield data that improve the manner in which patients are diagnosed and treated.

The importance of model validation cannot be overemphasized, yet validation studies are not popular because they are time-consuming, and in general, lack clinical relevance. For these reasons, model validation is often included as a subsection of a larger study, as was the case in the work presented by Maquer and colleagues. Reporting the accuracy of computer models as a substudy is better than ignoring validation altogether, but it is a risky endeavor, as important technical details and results may be lost. To avoid this issue, we must ensure that modeling studies are rigorously reviewed and the reporting of technical details is encouraged, independent of whether the manuscript is submitted to a basic-science or clinical journal.

Demonstrating that a model provides predictions that can improve patient care seems intuitive, but in practice, is very challenging. Results by Maquer and colleagues seem to advocate for more-aggressive resections, which could reduce failure rates caused by under-resection. However, it may be of greater clinical relevance to first answer the question: “What resection depth is necessary to improve range of motion, eliminate pain, and normalize chondrolabral contact mechanics?” Once this question is addressed, we can evaluate if that particular resection is safe in terms of avoiding iatrogenic fracture. Considerable work has been done to develop, and in some cases, commercialize, software to visualize how various resections alter ROM [3]. While these programs incorporate patient-specific bony anatomy, they do not input kinematics measured for that particular patient, nor do they model the cartilage and acetabular labrum. Future models should integrate the morphology of bone and soft-tissue into models that are driven by patient-specific kinematics and kinetics to afford a more comprehensive understanding of why osteoarthritis develops in hips with FAI, and the extent to which surgery normalizes hip anatomy and function.

Models that include accurate three-dimensional bony and soft-tissue anatomy along with patient-derived

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kinematics and kinetics are inherently complex. However, one should not assume that a more-complex model is necessary; the required complexity of a model will ultimately depend on the research question that is asked. As an example, it has been shown that FE predictions of acetabular cartilage contact stress are insensitive to the changes in the stiffness of trabecular bone [1]. In this case, trabecular bone can be ignored, which greatly reduces computational time. However, the investigator must first provide evidence that exclusion of each parameter is justified. The ideal approach would be to incorporate as many patient-specific variables as possible, and then, one at a time, assess the influence of these variables on the predictions of interest. This is a tedious process. As such, we need to exercise patience to those developing and validating computer models in orthopaedics.

How Do We Get There?

We must first acknowledge that despite the clinical evidence, we still lack quantitative data demonstrating the relationship between altered anatomy and hip function in patients with FAI. Given the anatomical characteristics of hips with FAI, it is highly unlikely that generic models, such as those that assume the hip to be a

perfect ball-and-socket joint, or assign simplified kinematics, will greatly enhance our understanding of this condition. Fortunately, we are nearing an era where anatomically-accurate FE models, which predict cartilage and labrum contact mechanics [4], will be driven by in-vivo motion data obtained using techniques such as dual-fluoroscopy [5]. Unfortunately, these techniques require specialized knowledge and resources. We should thus advocate for the sharing of data, resources, and expertise. Such a platform could be similar to that pioneered by Dr. Scott Delp at Stanford University, where musculoskeletal modeling software is free to the public, and an entire online community has been established to disseminate these models (<https://simtk.org/>).

Finally, the environment in which models are published should be refined such that investigators are encouraged to release more-comprehensive datasets. Fortunately, data can now be submitted as supplemental material for most orthopaedic journals. Investigators should exploit the use of supplemental data, and to increase visibility, journals should consider publishing special issues devoted to computational modeling. To increase peer acceptance, editors should ensure that an expert in computational biomechanics has been recruited to review each manuscript on this topic,

similar to the way that journals receive assistance from methodologists for studies involving unfamiliar or complex statistics.

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