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APPLICATION OF VALIDATED COMPUTATIONAL MODELS OF PROXIMAL HUMERUS FRACTURE FIXATION TO GUIDE CLINICAL PRACTICE

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Fixation of osteoporotic proximal humerus fractures remains challenging. The 18-35% failure rate of the state-of-the-art locking plating indicates the need for improved solutions. Validated computational models may help to complement or even replace conventional experimental testing, expedite implant optimization and development, and support clinical decision making. However, prediction of the cyclic failure of bone fracture fixations remains challenging due to the not yet fully understood fatigue behaviour of the bone-implant interface and the enormous computational efforts that would be required to model these details. Nevertheless, simplified, but relevant solutions are required to provide immediate answers to clinical questions in an efficient way and with reasonable computational costs.

We have recently developed homogenized finite element (FE) models of proximal humerus fracture fixations and demonstrated that local elastic principal strain averaged around the screws can predict fatigue failure of the entire construct ($R^2 = 0.90$). The present study demonstrates how this approach can be utilized to guide clinical practice in several aspects including the selection of screw length, screw configuration and plate position.

Using an automated simulation framework, FE models of 26 low-density humeri were generated from high-resolution peripheral quantitative computer tomography (HR-pQCT) images. Instable three-part fractures were simulated and fixed with the PHILOS plate (DePuy Synthes, Switzerland). Isotropic linear elastic material properties of bone elements were assigned from the CT-based bone mineral density values. Three physiological loading modes were simulated with the forces imported from musculoskeletal models. The average principal strain around the screws was evaluated and used to predict cyclic construct failure by means of a previously identified relationship.

Screw length was found to have a significant effect with a smaller tip-to-joint distance providing higher stability. Out of four different screw configurations, the one utilizing the calcar screws of the PHILOS plate performed the best. Plate position had no significant effect when using four head fragment screws, but already a 2 mm proximal shift significantly improved and a 2 mm distal shift significantly reduced the predicted implant stability for a six-screw fixation.

The results are expected to help providing practical recommendations on the implant usage towards improved primary implant stability and may lead to better healing outcome of osteoporotic proximal fracture patients. The simple strain-based outcome metric offers an efficient surrogate measure of cyclic fixation failure and enable high-throughput studies.