TOTAL WRIST ARTHROPLASTY: A FINITE ELEMENT STUDY

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SUMMARY
Little is known about the mechanical effects that total wrist arthroplasty has on the arthritic wrist. Many clinical studies have presented poor long term functionality with high revision rates. This study presents a finite element model aimed to map the load transfer changes in the wrist after a total wrist arthroplasty.

INTRODUCTION
Computational models of the implanted hip and knee are well established in the literature and the knowledge obtained from them can be credited for the success rates of these operations. To date few finite element models of the implanted wrist exist and the ones available are subjected to simplifications or have carried out the analysis ex-vivo.

METHODS
The wrist of a healthy subject was imaged using a 3T clinical MRI scanner. The scans ranged from the distal end of the radius and ulna to the proximal third of the metacarpals. The total length of the scans was 64 mm and the resolution was 230 x 230 µm in plane and slice thickness was 0.7 mm. The scans were imported into Mimics (Materialise) where the edge detection of the bones was carried out. Three dimensional models of the bones were created. An STL file of the prosthesis was obtained and imported into Mimics where, using boolean operators, the proximal component of the prosthesis was implanted into the radius and the distal component placed on top, removing the lunate and the distal aspects of the scaphoid and proximal aspect of the capitate.

The two components and bones were meshed using a triangular surface mesh in Mimics and the meshes were exported into Abaqus (v.6.10EF) where the surface meshes were converted into volumetric mesh using tetrahedral C3D4 elements. In Abaqus the assembly was created and contact established between each articulation. It was assumed that between the carpal bones and the prosthesis no relative movement would occur and tie constraints were applied. Frictionless contact was assumed between the carpal bones. Loading was applied as compressive forces through the metacarpals. The force values were obtained through a biomechanical study where grip force was measured using five 6-degree-of-freedom force transducers in conjunction with an 8 camera Vicon system. Biomechanical model was used to convert the measured external forces into joint contact forces applied to the finite element model. Ligaments were created using non-linear spring elements with material properties obtained from previously published studies.

RESULTS AND DISCUSSION
The model was solved using the Explicit algorithm in Abaqus simulating a quasi static behaviour.

The load transfer characteristics were compared to the healthy wrist. It was found that the implanted wrist will transfer much higher ratio of loading through the radius than the ulna compared to the healthy subject, which can be explained by the absence of the lunate. High stress concentration was seen in the carpal bones articulating with the distal component of the implant. Additionally, different ligament behavior was seen as the dorsal radiotriquetral ligament which plays a significant role in the joint stability in the healthy subjects, carried little loading in the implanted wrist. The palmar scapho-triquetral ligament was the highest loaded ligament in the implanted wrist.

CONCLUSIONS
The biomechanical changes that occur after total wrist arthroplasty can be quantified using finite element analysis. By carrying out a systematic simulation of the prostheses commercially available and compare with clinical findings, it could be possible to improve the existing designs in order to achieve better long term functionality for patients suffering from wrist disorders.

REFERENCES