

The three dimensional load transfer characteristics of the wrist during maximal gripping.

¹M.K. Gíslason, ¹N.K Fowler and ²D.H. Nash.

¹ Bioengineering Unit, University of Strathclyde; email: magnus.gislason@strath.ac.uk

² Department of Mechanical Engineering, University of Strathclyde

INTRODUCTION

Wrist instability is a common problem post trauma or through arthritic changes and this can have a profound effect on hand function. With the increasing number of surgical treatments available for the painful wrist, there is a demand for more detailed information on the normal load transfer characteristics of this complex joint. Previous cadaveric studies have measured intra-carpal pressure using pressure sensitive films or conductive rubber [1]. Surface mounted strain gauges have also been used to measure strain levels on a limited number of carpal bones. Both these methods require invasive disruption of the materials under study. A limited number of computational models have been developed but due to the complexity of the wrist joint, many of these have been a two dimensional approach to what is in reality a three dimensional problem. In addition they do not include all 15 bones involved in load transmission or use theoretical/arbitrary loading conditions rather than measured data [2].

The aim of the current study was to develop a fully-representative three-dimensional finite element model of the entire wrist joint in order to study the transmission of force through the carpus during a functional activity. Real biomechanical data were used to define the boundary conditions and the contributions from cartilage and ligaments were incorporated into the model.

METHODS

High resolution 3 Tesla MRI sequences were obtained from a single male subject, with in-plane (axial) resolution of 250x250µm and a slice thickness of 750µm. The MR images were imported into Mimics [3] software where solid models of 15 bones were created (distal sections of radius and ulnar, 8 carpal bones and proximal sections of 5 metacarpals). Physical material properties were assigned according to the pixel grayscale values of the different regions of the MR-image. Regions of cartilage, cortical bone and cancellous bone were defined with transition zones between the different layers. A finite element mesh was created in Abaqus [4] from 10-node tetrahedral brick elements (figure 1). Ligaments were modelled with non-linear spring elements and their origin and insertion points were evaluated manually according to previous anatomical studies.

A series of biomechanical trials were conducted to obtain subject specific loads during a whole hand maximal grip activity. Five six degree-of-freedom force transducers in a grip device were used in conjunction with VICON motion analysis to define the three dimensional load systems applied to each metacarpal according to its coordinate system. These data were applied as loading/boundary conditions in the finite element model to simulate the grip activity.

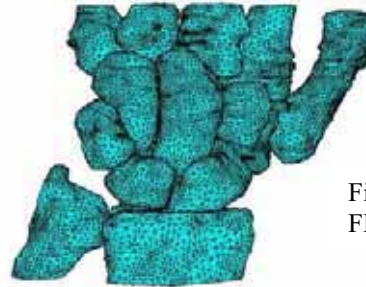


Figure 1: Dorsal view of the FE mesh.

RESULTS AND DISCUSSION

Model results showed that 95% of the load applied to the metacarpals was distributed through the radius and only 5% through the ulna. Previous studies have shown the same ratio to be 90%-radius, 10%-ulna [5]. This discrepancy is consistent with the fact that the current wrist modelled had a negative ulnar variance and the force distribution was determined by the bony anatomy. Approximately 60% of the total load was transmitted from the metacarpals through the trapezoid-trapezium-scaphoid junctions (figure 2). This result is coherent with clinical evidence as the junction between the first metacarpal and the trapezium is a common site for wear.



Figure 2: Trapezoid-Trapezium-Scaphoid force transmission.

CONCLUSIONS

This study is an attempt to provide three dimensional finite element modelling of a complete wrist joint using real biomechanical boundary conditions. The results are consistent with previous work but reveal the importance of considering variations in wrist joint anatomy. Future work using this technique will investigate the effects of anatomical variation on wrist joint kinetics.

REFERENCES

1. Tencer AF et al., *J. of Orthop. Research* 6,509- 517,1988.
2. Carrigan S.D., et al.. *Annals of Biomedical engineering* 31, 718-725, 2003.
3. Materialise, Leuven, Belgium.
4. ABAQUS Inc., Providence, RI, USA
5. Anderson D.L., et al. *Seminars in arthroplasty* 6, 1, 30-36, 1995.

ACKNOWLEDGEMENTS

This work was supported by Arthritis Research Campaign grant no. 15468.