Effects of Partial Wrist Arthrodesis on Loading at the Radiocarpal Joints

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Introduction

The radiocarpal joint plays an important role in the stabilization of the wrist joint. Degenerative diseases such as rheumatoid arthritis can destabilize the joint and compromise the kinematics of the carpal bones. Partial wrist arthrodesis in the rheumatoid wrist has been popular since its introduction in 1983 [1]. The procedure prevents ulnar drift of the carpus and prevents progression to a subluxed state as well as providing pain relief for the patient. The biomechanical consequences of arthrodesis at the radiocarpal joint have not been extensively explored. This study looks at the biomechanical changes on the load transfer through the radiocarpal joint after partial wrist fusion.

Materials and methods

A finite element model was created of the wrist using 3T MRI scans from the distal end of the radius and ulna to the proximal third of the metacarpals. The scans were imported into Mimics (v.12.1 Materialise) where edge detection and 3D object creation of the carpal bones were carried out. Meshes of triangular surface elements were imported into Abaqus (v.6.9 Simulia) and converted into 3D tetrahedral elements. Ligaments and tendons were modelled using non-linear spring elements. Contact areas between each bone articulation were identified manually and the mesh extruded at those locations, creating wedge elements representing the articular cartilage. It was assumed that no force was transmitted through the joint until clearance between the surfaces was 0. Physiological loading, derived using a biomechanical analysis of gripping, was applied as compressive force acting along the long axis of each metacarpal. The analysis was carried out using the explicit solver where a quasi static behaviour of the model was assumed. Four types of modelling conditions were analysed:

1. Untreated wrist
2. Radiolunate fusion
3. Radioscaphoid fusion
4. Radiolunate and Radioscaphoid fusion

The arthrodesis was simulated by tieing together the nodepoints at the treated articulation, thus not allowing any movement between the two corresponding bones.

Results and discussion

For the untreated wrist it was found that the load was distributed equally through the radioscaphoid (RS) and the radiolunate (RL) articulations. When arthrodesis was 'performed' large changes were seen in the magnitudes and angles with which the two reaction forces acted (in the postero-anterior (radial/ulnar) plane; α at the radio-scaphoid and β at the radio-lunate articulation). Positive angle values are directed radially and negative angle values are directed ulnarly. The values are listed in table 1.

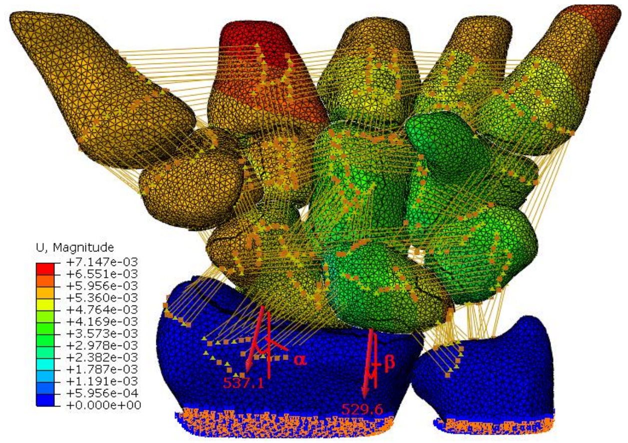

Fig. 1: Displacement plot for the untreated wrist with reaction forces acting on the radio-scaphoid and radio-lunate joints. Magnitude and direction of the joint reaction forces are illustrated with red arrows.

Condition	RS [N]	RL [N]	α [°]	β [°]
1	537.1	529.6	15.3	6.8
2	403.8	418.7	18.3	-37.7
3	547.0	439.2	-29,7	2.9
4	569.0	358.1	-29.4	-19.2

Table 1: The magnitude and angle of the reaction forces acting on the radiocarpal joints for the four conditions.

Fusing the radiolunate joint, decreased the forces on that joint as well as for the radioscaphoid joint, whereas fusing the radioscaphoid joint increased the loading on that joint, but decreased loading on the radiolunate joint. The direction changes of the resultant forces travelling through the joints suggested that the fusion of the joints helped absorb the shear forces acting ulnarly on the carpus, thus unloading most of the ligamentous mechanism constraining the radiocarpal joint. The load ratio between the radioscaphoid and the radiolunate articulation was higher than previously reported [2]

Conclusion

The results suggest that large changes occur in the load transfer characteristics of the wrist during a partial wrist fusion.

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References

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