Modeling the Length of Wrist Ligaments

E. Marai, S. Andrews, C. Grimm,
D. Laidlaw, Dr. J.J. Crisco

Introduction

According to a study performed at RI Hospital, some patients still display wrist mobility constraints, though apparently no bone interactions cause loss of mobility. One possible explanation is that the mobility problem in these cases is caused by the ligaments that link the bones. Unfortunately, there is not enough known about wrist mechanics, mostly because of the lack of an appropriate wrist model. However, it would be possible to add ligament information to an existing wrist bone model, and this is the goal of our research. We hypothesize that there is a correlation between variation in ligament length and wrist mobility constraints.
The model we created shows how the lengths of distal radioulnar ligaments modify as a function of rotation angles. This allows us to identify differences between the results obtained for uninjured and injured wrists. We conclude that there is indeed a link between ligament length and wrist mobility problems.

Methods

Our ligament length model is based on the existing wrist-bone model developed at Brown ([1]), and on anatomy book data. We started by adding ligament insertion point information to the bone model. We selected insertion points interactively, based on medical papers information ([2],[3]). In the case of uninjured wrists ligaments can be succesfully approximated by line segments (the ligaments do not touch the ulna seat). In the case of injured wrists however we had to use critical control points located on the surface of the ulna seat and approximate the minimum length paths by polylines which stick to the surface of the bones. We later evaluated the lengths of these paths and how they modify as a function of rotation angles. We represented modification of each ligament length as a function of rotation angles in 2D graphs; the graphs proved to be of great help during the final stage of our project, which was comparison of modification of injured wrist ligament length versus modification of healthy wrist ligament length.

Results

Our model ([4]) confirms that in the case of healthy wrists distal ligaments do not touch the surface of the ulna during rotation. Our measurements show that in fact the length of distal ligaments is not a monotonically increasing/decreasing function of rotation angles, as previous measurements on cadaver wrists suggested. On the contrary, it appears that both ligaments reach a global/local maximum length in the neighborhood of the neutral position (see Figure 1).
The distance between the radius head and the head of ulna increases in the case of injured wrists. This causes an increased length of both dorsal and palmar distal ligaments. More important, our model shows that actually in the case of injured wrists the ligaments are forced to touch the bone surface. Given the sudden sinking movement of the radius between neutral position and supination, the distal ligaments lean on the surface of the ulna seat, and are forced to follow its curvature. Thus they are subjected to a significant additional stress, which causes them to lengthen beyond the expected maximum length (Figure 1).
We can conclude thus that, as expected, there is indeed a dependency between change in ligament length and change in wrist mobility. The surprise comes from analyzing the length function: contrary to our expectations, constraints in wrist mobility are not associated with reduced ligament length. On the contrary, it seems that ligaments adjust/increase their length in order to obey the strange bone movement.

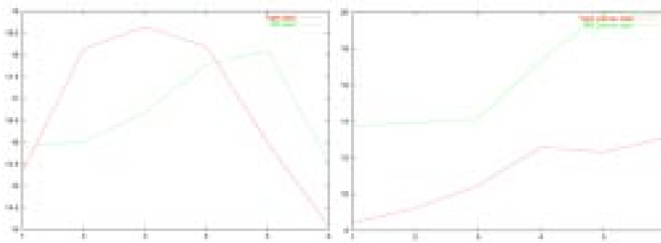

Figure 1: Distal ligament lengths as functions of rotation position (red - healthy wrist, green - injured wrist; left image: palmar ligament, right image: dorsal ligament)

Conclusions

Our research suggests that in fact CT and anatomy book data suffice in order to show whether there is a dependency between change in ligament length and change in wrist mobility. We expected drastic limitations of wrist mobility (characteristic to the patients we considered) to show drastic limitations of ligament length, even taking into account the possible length-estimation errors due to the lack of appropriate MRI data. The surprising result was that, on the contrary, drastic limitations of wrist mobility are undoubtedly associated with increased ligament lengths.
We see this as the start of the first wrist ligament model. This model could be later enriched with additional MRI data. It is likely that MRI data would provide more accurate information about location of insertion points for specific patients; however this will not bring major modifications to our model, since we try to model length of ligaments and not surface or shape of ligaments.

References

[1] /map/gfx0/common/hand/cagatay/distanceVisualization/forearmAnim/rightHandColored/vis2

[2] Linscheid, R., Biomechanics of the Distal Radioulnar Joint, Clinical Orthopaedics, Feb. 1992

[3] Schuind, F., Kai-Nan An, Berglund, L., Rey, R., Cooney, W., Linscheid, R., Chao, E., The Distal Radioulnar Ligaments, The Journal of Hand Surgery, Nov. 1991

[4] /map/gfx1/common/hand/Ligaments/