USE OF SURFACE SENSORS TO REPRESENT BONY SEGMENTS TO MEASURE THUMB CARPOMETACARPAL JOINT MOTION

Fong-Chin Su[1], Li-Chieh Kuo[1,2], William P. Cooney, III[2], Kenton R. Kaufman[2] and Kai-Nan An[2]
[1]Institute of Biomedical Engineering, National Cheng Kung University, Tainan, Taiwan, fcsu@mail.ncku.edu.tw
[2]Biomechanics Laboratory, Department of Orthopedics, Mayo Clinic/Mayo Foundation, Rochester, Minnesota, U.S.A.

INTRODUCTION

Previous studies verified the feasibility of surface markers to represent finger and thumb kinematics using the video-based motion analysis system by comparison with fluoroscopy (Rash et al., 1999; Kuo et al., 2002). However, those were two-dimensional measurements. Magnetic-tracking systems have been developed for measuring joint kinematics. Based on the concept of the three-dimensional (3D) space within which the thumb metacarpal bone can move, the current study proposes a 3D method for evaluating the relationship between the skin and bony segment. The objectives of this study were to investigate the feasibility of using a skin sensor to represent the first and third metacarpal bone, to verify that there was no significant relative motion between the skin of the third metacarpal bone and trapezium bony segment.

METHODS

Eight hands from fresh-frozen human cadavers were disarticulated 4 cm proximal to the wrist joint and used in this experiment (Fig. 1). The 3D motion of the carpometacarpal (CMC) joint was recorded with an electromagnetic tracking device at the frequency of 30 Hz (3-Space Tracker System, Polhemus, Inc., Colchester, VT). The first sensor (S1) was transfixed to the first metacarpal bony segment and the second one (S2) was mounted on the skin of the head of the first metacarpal. These two sensors were used to determine the relationship between the skin and the bony segment while moving the thumb. The third sensor (S3) was transfixed into both the trapezium and scaphoid. The fourth sensor (S4) was attached on the skin of the dorsal aspect of the head of the third metacarpal.

Three maximal movements of the CMC joint were included in the experiment. Circumduction (CIR), Flexion/Extension (F/E) and Abduction/Adduction (ABD/ADD) of the thumb CMC joint were performed passively under a constant load of 100 g. The Eulerian angles were used to assess the relative angular changes of the coordinate systems between the S1-S2 and S3-S4.

RESULTS AND DISCUSSION

Most of the intraclass correlation coefficient (ICC) values of the specimens are larger than 0.75 and the range of the mean values of the ICC is between 0.84 and 0.98. These results indicate a high similarity between the two different sensors for each planar movement. The averages of the angle differences of the S1 relative to S2 and the S3 relative to S4 are smaller than 4.92°. The Root Mean Square (RMS) of the translation between sensors is less than 2.6 mm.

Thus, the effect of the skin artifact was within allowable ranges. Therefore, it is feasible to collect motions of the first metacarpal by attaching skin sensors to the metacarpal head as a substitute for the bony segment. Moreover, after observing the rotation and translation results from the S3 and S4, we also found that there were no significant movements between these two sensors. Thus, we can use a skin sensor attached on the dorsal aspect of the third metacarpal head to represent the bony segment of the trapezium bone to overcome the clinical difficulties when measuring the CMC joint kinematics.

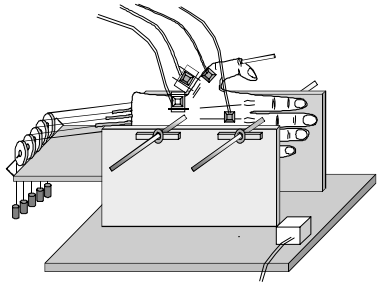

Figure 1: Schematic of equipment used in this study. The hand was securely transfixed with a plastic rod stabilized to a plastic frame with constant loads applied to the tendons.

SUMMARY

These data revealed that the similarities of the two sensors throughout the motion cycle were high. The differences between the two sensors were also within clinically allowable range of ±5°. Therefore, it is feasible to collect motions of the first metacarpal by attaching the skin sensors at the metacarpal head to measure the bony segment.

REFERENCES

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Table 1: The ranges, mean, standard deviation and coefficient variance of the angular differences between the bony (S1) and skin (S2) sensors in three controlled movements (unit: degree)

Movement	CIR			F/E			ABD/ADD		
Difference	X	Y	Z	X	Y	Z	X	Y	Z
Ranges	2.15-5.95	1.62-7.44	0.89-6.38	1.22-6.55	1.28-6.74	0.89-2.83	1.47-4.95	1.04-6.85	0.51-5.26
Mean	4.29	4.92	2.77	3.16	3.98	1.91	3.08	3.29	1.95
SD	0.71	0.63	0.42	0.35	0.45	0.24	0.44	0.36	0.28