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KINEMATIC ANALYSIS OF THE HUMAN ELBOW

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This note describes a simple method for making a kinematic analysis of the elbow for the purpose of confirming how closely the elbow can be considered a pure hinge joint and for determining the location of this hinge point in order to properly design and fit a lower arm orthotic device. An anatomical description of elbow motion has been given by Taylor (*2*) and many others. The radius and ulna are generally considered to rotate about the elbow axis in the manner of a simple hinge.

Assuming planar motion, the relative motions of two rigid bodies such as the forearm bones can be described by two curves called the fixed and moving centrodes. The moving centrode rolls without slip on the fixed centrode as shown in Figure 1. There is a unique pair of centrodes for any given relative motion. While there are other methods for describing relative planar motion between two rigid bodies such as a generating curve and an envelope, the centrode method proves to be the easiest to obtain experimentally and a simple apparatus was designed which measures and records the motion of the elbow joint. From this data, the centrodes can be determined. The method is similar to that described by Freudenstein and Woo (*1*) for the analysis of knee motion.

One of the two members (rigid bodies) is stationary while the other is allowed to move with its natural motion. At least two marking pens attached to the moving member at two different positions such as A and B in Figure 1 trace out different paths (A – A′ and B – B′) while the member moves. There must be a means of identifying points on the two curves which were traced at the same time. A point on the fixed centrode is determined by erecting a normal (i.e., a perpendicular to the tangent) to each curve at any such pair of points. The intersection of these two normals determines one point on the fixed centrode. This process is repeated for many pairs of points on the two curves traced out by the moving member. The curve fitted through the resulting series of intersection points becomes the centrode.

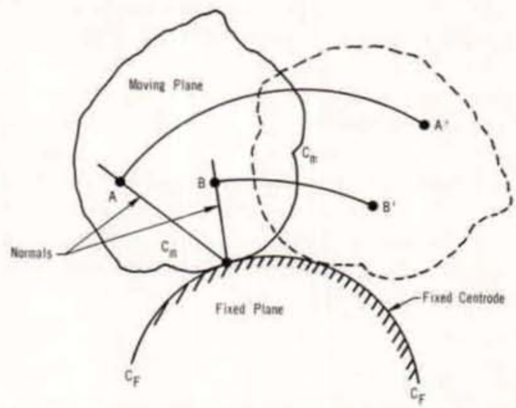

Fig. 1. Fixed and Moving Centrodes

EXPERIMENTAL DETERMINATION OF THE CENTRODE

The apparatus is shown in Figure 2. The upper arm is held rigidly against a horizontal board while the lower arm sweeps from full flexion to full extension along side a vertical board. A pen

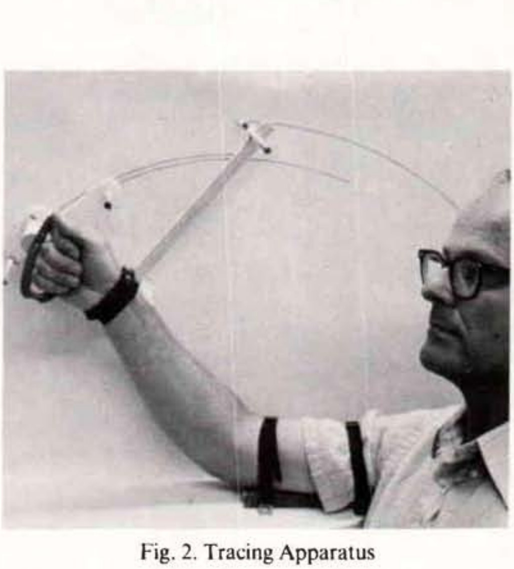

Fig. 2. Tracing Apparatus

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holder strapped to the lower arm records three point paths on the board. The wrist joint is wrapped to prevent motion. The elbow is placed against a dowel for initial positioning with the arm in full flexion, and the upper arm is strapped in place. When the dowel is removed, the lower arm can be placed in full extension. While the three point paths are being traced, the board is vibrated lightly so that reference marks are left spaced along the three paths and it is then possible to know the simultaneous positions of the three pens at several positions along the paths. The intersection of the normals determines a point on the centrode of the upper arm (Fig. 3). While only two normals are necessary, the third serves as a check on accuracy. Eighty percent of the intersections of all the normals were found to be in a circle of diameter 7.95 mm (.313 inch). The centrode of the lower (moving) arm could be determined by the inverse process but this was not carried out for reasons described below.

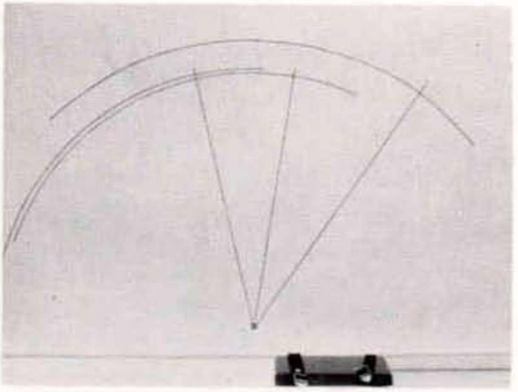

Fig. 3. Determination of a Point on the Fixed Centrode

DISCUSSION AND RESULTS

Since the fixed centrode lies within a 7.95 mm (.313 inch) diameter circle, it is clear that regardless of the shape of the moving centrode, the elbow joint can be closely approximated by a pure hinge. Indeed some of the deviation from pure hinge motion may well be caused by cartilage compression, muscle action, stress on the elbow due to load, etc. A check on the accuracy of this approximation was made by retracing the three point paths with a compass placed at the center of the 7.95 mm circle. The greatest deviation from the original paths was .76 mm (.030 inch).

Since the elbow may be reinserted into the measuring device after the data has been reduced and the pivot point found, the axis of the elbow hinge can be clearly marked on the test subject. If the patient is to be fitted with an orthotic device, he should of course be wearing the cuff or sleeve on the upper arm that will be used in the device during both the determination of the centrode and during the determination of the hinge point.

REFERENCES

1. Freudenstein, F. and L. D. Woo, Kinematics of the human knee joint, *Bull. Math. Biophysics*, 31, 215–232, 1969.

2. Taylor, C. L. in "Human Limbs and Their Substitutes" (edited by P. E. Klopstog and P. D. Wilson), pp. 192–198, Hafner, New York.