HOW ACCURATELY CAN WE MEASURE THE INSTANTANEOUS AXIS OF ROTATION?

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INTRODUCTION

The instantaneous axis of rotation (IAR), which represents relative motion as a single three-dimensional vector, has been gaining acceptance as a metric for assessing total disc replacement (TDR) performance. IAR is determined experimentally through motion tracking of physical targets that are attached to spinal levels of interest. Regardless of the motion tracking system, intrinsic experimental errors are present in all target position measurements, and these errors propagate into IAR calculations. There is controversy in the literature as to the magnitude of these errors and the best practices for their minimization. The objective of this study was to determine whether current techniques for IAR measurement are sufficiently accurate for TDR performance assessment. A physical validation experiment was used to quantify IAR error, and the implications of IAR error in determining TDR performance were illustrated for a biomechanical test of the ProDisc®-L (Synthes Inc. West Chester, PA USA).

METHODS

A simple validation experiment was performed to quantify experimental error in IAR and to compare the efficacy of different error-minimization algorithms. Four optical targets were mounted to the rotating arm of a linear hinge joint. Target positions were measured at various flexion angles using a commercial, optical-based motion tracking system (Motion Analysis Corp., Santa Rosa, CA). To simulate variability during multi-session biomechanical testing, multiple trials (N=15) were conducted with the targets repositioned and the motion tracking system recalibrated between trials. Target positions were converted into IAR measurements using two different kinematic algorithms: 1) a direct solve approach (Kinzel 1972), and 2) an optimization algorithm (Bar-Itzhack 2000). Error bounds on IAR location, as defined by the intersection of the IAR vector with the mid-sagittal plane of the TDR, were determined from the validation experiment and applied to an in vitro biomechanical study of a TDR system. One lumbosacral spinal section (L5-S1, 56 y.o. male) was instrumented with a ProDisc®-L device and loaded to 1100 N in combined axial compression and anterior shear. The effect of surgical placement on IAR was determined by repositioning the implant +3 mm from the central position in the sagittal plane.

RESULTS

Data from the validation study indicated that the error for the optimization algorithm (+6mm) was substantially less than the direct-solve approach (+12mm). This
error obscured measurements of change in IAR location with TDR positioning. Biomechanical test data indicated that the IAR migration associated with a 3 mm anterior shift of the TDR (3 mm posterior and 1 mm inferior) was less than the minimal detectable change in IAR position using our test system.

**DISCUSSION**

The results of this study suggest that current techniques for IAR measurement are insufficient for TDR performance assessment. Although the use of a more sophisticated kinematic algorithm improves accuracy by 200%, IAR position can only be determined to within ±6mm, which may be too large to detect clinically significant changes in IAR that occur with device repositioning or migration. There is clearly a need to develop an alternative metric to IAR for three-dimensional motion assessment that is less sensitive to intrinsic experimental errors.