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REVIEWER'S COMMENT

Reviewer's comments concerning "Biomechanical evaluation of segmental instability in degenerative lumbar spondylolisthesis" by K. Hasegawa et al. (ESJO-D-08-00441R1)

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In this study, a controlled cyclic motion was applied intraoperatively separating and bringing together the tips of adjacent spinous processes in degenerated and adjacent normal lumbar spinal motion segments (SMSs) of patients undergoing a surgical procedure for degenerative lumbar spondylolisthesis (DLS). The purpose was to investigate the biomechanical properties of DLS segments. The most interesting aspect of this study was the intraoperative method used to assess SMS dynamics. Although ex vivo testing with application of free moments and follower loads may well simulate physiological loading conditions, we are all aware of the artifacts, which may be created by lack of muscular activity, both paraspinal and abdominal, and due to specimen preparation and storage. It can of course be argued that anaesthetized patients and surgical approaches may also have their own artifacts, but surely intraoperative in vivo measurement are one step closer to the physiological condition. Although the data presented in this publication is valuable, there are some concerns with the biomechanical and clinical interpretations.

The authors interpret that the increasing/decreasing distance between adjacent spinous processes is due to flexion/extension across the segment, but this may not be strictly correct. The measured distance is a resultant of any and all SMS motions, e.g. translations and axial rotation. In an unpublished experiment, they determined with independent measurements of axial and sagittal rotation that for an intact pig spine the amount of resultant displacement between spinous processes correlated well to the flexion/extension angle. Although this result may translate to normal human SMSs, coupling between pure rotations and translations [1] may be quite different especially when there is joint laxity and degeneration such as in DLS. Furthermore, the neutral zone (NZ), which they found to have the greatest difference in dynamic behaviour between normal and DLS segments, was defined by the authors in a non-standard manner. The NZ is commonly understood to be "…starting from the neutral position up to the beginning of some resistance offered by the joint. The unit of measure is the meter (foot) for translation, or the radian (degree) for rotation," as defined by White and Panjabi [2]. The authors define it as "the reciprocal of the load necessary to displace the distance between the two tips of the holders from −5 mm (flexion) to +5 mm (extension)." Hence, it is difficult to understand what exactly is the most significant difference found between DLS and normal segments and to relate these results to that in other studies where standard outcomes were measured.

Another issue raised by this study is the clinical interpretation. It is not clear exactly for what purpose the authors carried out this study and what is its clinical relevance. The authors claimed that their purpose was to establish a reliable system to obtain the biomechanical data, which can be referred to for treatment selection. However no reliability of measurements were examined. What they did observe was that the NZs of normal segments were all less than 2 mm/N whereas those with DLS were mostly $\geq$2 mm/N with some less than 2 mm/N. Based on this, they concluded that: (1) NZ as they measured is a good indicator of instability; (2) segments with spondylolisthesis are not always unstable and therefore fusion to these segment is not always necessary; and (3)

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surgeons may be able to determine if fusion is necessary by measuring NZ with this measurement system. The cut-off of 2 mm/N seems to be rather arbitrary in a clinical sense and is based on measurements of only 6 segments. What is the clinical significance of 2 mm/N in terms of "stability"? Six segments seem to be a rather low number of samples to determine population based thresholds and can adjacent segments in spines with DLS be considered "normal"? If a more standard measure of NZ had been used and if the measurements could have been converted to true flexion/ extension angles, the threshold for "instability" could have been compared to other studies in which a large number of normal SMSs from non-diseased spines were tested. As for the authors' inference to decision making concerning fusion, since the outcome of fusion or no fusion was not assessed in a sufficient number of patients, such inference do not seem to be well supported by the data presented in this study.

In spite of these concerns, the possibilities presented in this study are intriguing. By combining with CT or 3D fluoroscopy registration and 3D tracking used for computer aided surgical navigation, de-coupled standard motions calculated from the resultant maybe possible. These could then be compared to similar baseline measurements in normal cadaveric spines to biomechanically characterize the diseased segments, as deviations form normal. Finally, by combining intraoperative measurements with analysis of outcome measures, the value of such measurement to the clinical decision making process may be demonstrated and a truly unique functional assessment may become possible.

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