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In Vivo Analysis of Intervertebral Kinematics: Differences between Standing Active and Recumbent Passive Bending Modes

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Abstract

Current cadaver-based methods for performing biomechanical testing of non-fusion spine implant devices are predicated on the assumption that the intervertebral kinematics observed during *in vitro* studies of the spine are representative of the kinematics that occur *in vivo*. Until recently, difficulties with quantitatively measuring *in vivo* spine kinematics have made it impossible to test this assumption. The KineGraph VMA (Ortho Kinematics, Austin, TX), a novel testing method for assessing *in vivo* intervertebral kinematics, has made it possible to measure the extent to which *in vitro* approaches correlate to *in vivo* behavior. Recently collected KineGraph VMA data has shown that current *in vitro* testing approaches are failing to adequately mimic *in vivo* behavior in at least one important and potentially clinically-relevant way.

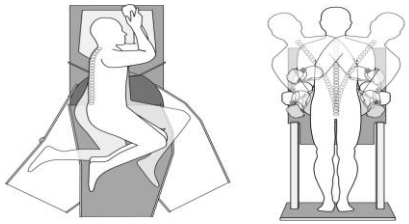


Figure 1: Powered motion devices. Left: The recumbent device provides passive, unloaded spine bending. Right: The standing device provides guided active bending of the loaded spine.

Materials and Methods

The KineGraph VMA measures intervertebral kinematics by incorporating a patient handling device that standardizes trunk bending during fluoroscopic imaging (Figure 1) as well as image recognition software to automatically register and track vertebral bodies on fluoroscopic image sequences (Figure 2). This approach makes it possible to directly measure intervertebral motion continuously throughout the entire range of trunk bending (Figure 3), and is not subject to the high levels of inter/intra-subject variability associated with current *in vivo* testing approaches which rely on uncontrolled bending during imaging.

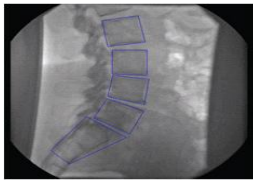


Figure 2: Fluoroscopic image of spine in flexion/extension bending with digitized vertebral borders.

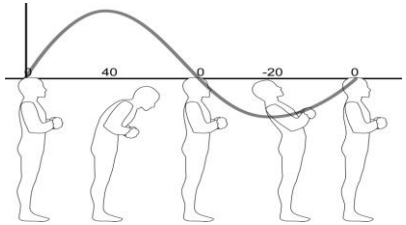


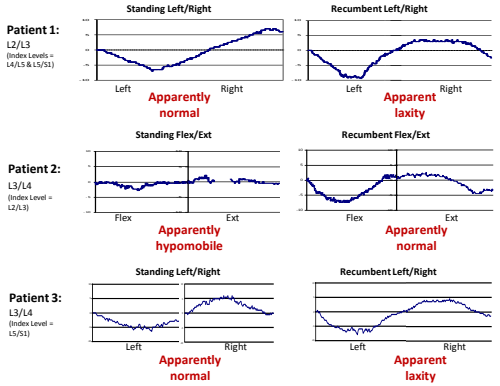
Figure 3: The output of the KineGraph VMA is reported in intervertebral plots, on which the intervertebral angle (IVA) is plotted as a function of the degree of trunk bending for each frame in the cine.

Ten stenosis patients were tested using the KineGraph in two bending modes: standing guided bending and recumbent passive bending. In each bending mode, patients were tested in flexion/extension and lateral bending, resulting in four bending routines for each patient. Plots of intervertebral motion vs. gross trunk bending were created for the patients' non-stenotic levels.

Results

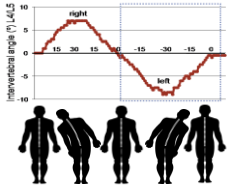
Any observed differences in the kinematic presentations between the two bending modes can be attributed to the effects of muscle involvement and/or normal gravitational loads. Among 10 patients studied at their non-operated levels, there were three that showed significant differences between these two bending modes, as shown in Figures 4a and 4b.

Figure 4a: KineGraph VMA Data for three Stenosis Patients:



Note that laxity is characterized in the KineGraph VMA motion plots as a "flat bottomed boat," indicating that the disc is not providing normal elastic function similar to the sinusoidal plots typical of what is observed among asymptomatic, shown below.

Figure 4b: Typical KineGraph VMA Data from an asymptomatic subject:



Typical motion plot, representative of those observed in asymptomatic subjects. The x-axis represents gross trunk bending, and the y-axis represents intervertebral rotation.

Conclusion

These clinical findings confirm that for lumbar spine patients, there can be dramatically different kinematic presentations at a given lumbar level dependent upon utilization of active muscles and/or physiologic weight-bearing loads. These differences can be large enough such that intervertebral motion can be normal in one bending mode and dysfunctional in the other. It is common for back pain patients to report acute bending-induced lumbar pain in lying down postures (i.e. moving in bed).

We conclude that motion preserving spine implant devices need to be designed and tested such that they replicate "normal" function in all operating conditions, including recumbent operational modes. Historically, standing, active bending modes have been the sole *in vitro* testing focus ignoring recumbent operational modes.

References

1. Breen AC, et al. An Objective Spinal Motion Image Assessment (OSMIA): reliability, accuracy, and exposure data. BMC Musculoskeletal Disorders 2006; 7:1-10
2. Mellor FE, et. al. Midlumbar lateral flexion stability in healthy volunteers by in vivo fluoroscopy. Spine. 2009; 34(22):E811-E817