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Design Optimization of a Posterior Dynamic Stabilization Concept for Restoring the Intact Biomechanics of Lumbar Spine after Facetectomy
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Background: Concept of posterior dynamic stabilization (PDS) is a recent alternative to traditional fusion surgery, and for stabilization after decompression surgery in treatment of spinal stenosis. PDS systems often include combination of various mechanical joints; however which combination would provide the most intact like biomechanics while having the least loads going through implant components is not yet known. We undertook finite element analyses to evaluate the effects of design variables on biomechanics of spine following factectomy and stabilization using a screw-based PDS system.

Methods: A nonlinear 3D, experimentally validated L3-S1 FEM was used. A total bilateral facetectomy was simulated at L4-L5 prior to placement of PDS. The PDS included a pair of curved male-female CoCr sliding components with a base radius of 45mm and its center of rotation (COR) matched that of intact disc. The radii of PDS were 30,40,50 and 55mm and a BS joint was attached bilaterally to either end of each PDS via a cross connector. A total of 15 implanted scenarios which included 5 radius variations each with three BS joint settings (NJ: no joint, BJ: joint at bottom and TJ: joint at top) were simulated. All models were loaded with 400N of pre-compressive load and 10Nm of moment to simulate flexion:Flex, extension:Ext, lateral bending:LB and lateral rotation:LR. The segmental motion and load sharing at discs and implants were computed for intact and implanted cases.

Results: The intact segment had motion of 2.7°, 5.0°, 4.5° and 2.4° in Ext, Flex, LB and LR respectively. At implanted level the motion varied between 2° to 3.9°, 3.3° to 5.2°, 1.3° to 4.5° and 0.7° to 2.4° for different PDS settings for the same loadings. When the ball joints were placed at caudal side, the motion was closest to intact. Also variation of curvature of PDS affected the segmental kinematics in each loading; the PDS with R45 (base) had motion closest to intact. Among all cases, PDS-R45 with joint at caudal side had intact like motion in all loadings. At adjacent segments, all implanted models had kinematics close to intact, L3L4: 2.4°, 5.0°, 4.7° and 2.6°; L5S1: 3.5°, 5.2°, 3.5° and 2.2° in Ext, Flex, LB and LR respectively. The intradiscal pressure across segments predicted similar changes as kinematics for all implanted cases versus intact.

The axial pullout load on screws increased (45 to 72N) in NJ cases and decreased (78 to 54N) in BS cases when radius of PDS increased. However in BJ models, the loads remained close to 60N independent of variations in the radius. The bending moment on screws didn't change much when the curvature varied in NJ (~2.1Nm) and BJ (~2.2Nm) cases. However it decreased as the radius increased in TJ cases (1.8 to 1.2Nm).

Discussion: Our results suggest that a design which has a matched COR with disc will provide the segment with kinematics similar to intact. Having the BS at the caudal end helps to keep the COR close to inferior endplate much like the intact. This would reduce the loads on screws thus lesser risk of implant failure in the long run.