Biomechanical Performance of Polycaprolactone (PCL)-based scaffold with rhBMP-2 in a Sheep Thoracic Spine Fusion Model

Yong, Mostyn[1,2], Brooker, Beau[1], Labrom, Robert[2], Askin, Geoffrey[2], Hutmacher, Dietmar[1,2], Adam, Clayton[1,2]

[1]Medical Device Domain, Institute of Health and Biomedical Innovation, Qld University of Technology, Brisbane, Australia
[2]Paediatric Spine Research Group, Mater Misericordiae Health Services, Mater Children's Hospital, Brisbane, Australia

Introduction: Adolescent idiopathic scoliosis is a complex three dimensional deformity affecting 2-3% of the general population. Resulting spine deformities include progressive coronal curvature, hypokyphosis, or frank lordosis in the thoracic spine and vertebral rotation in the axial plane with posterior elements turned into the curve concavity. The potential for curve progression is heightened during the adolescent growth spurt. Success of scoliosis deformity correction depends on solid bony fusion between adjacent vertebrae after the intervertebral discs have been surgically cleared and the disc spaces filled with graft material. Problems with bone graft harvest site morbidity as well as limited bone availability have led to the search for bone graft substitutes. Recently, a bioactive and resorbable scaffold fabricated from medical grade polycaprolactone (PCL) has been developed for bone regeneration at load bearing sites [1]. Combined with recombinant human bone morphogenic protein –2 (rhBMP-2), this has been shown to be successful in acting as a bone graft substitute in acting as a bone graft substitute in a porcine lumbar interbody fusion model when compared to autologous bone graft. This in vivo sheep study intends to evaluate the suitability of a custom designed medical grade PCL scaffold in combination with rhBMP-2 as a bone graft substitute in the setting of mini–thoracotomy surgery as a platform for ongoing research to benefit patients with adolescent idiopathic scoliosis.

Method: Within the scaffold design, a lay-down pattern of 0-90 degrees plus a semicircular scaffold contour confers additional strength for surgical handling and implantation of the prepared disc space using biodegradable PCL and the Dual Bioextruder, a computer–controlled extrusion-based additive manufacturing device developed at the Polytechnic University of Leiria, Portugal [2]. For mechanical testing, individual thoracic levels 4-5, 6-7, 8-9, 10-11 and 12-13 were carefully resected from the sheep spines. Each thoracic level consisted of a cranial and caudal thoracic vertebra and intervertebral disc together with in-situ stabilisation vertebral body screws and rod. The fixation devices were removed prior to testing. The cranial and caudal vertebrae of the defined level were potted in rigid dental cement and placed in a custom-made rig fitted onto an Instron MTS 8874 bi-axial testing machine that allows for unconstrained movement in response to applied loads.
Treatment levels rhBMP-2+PCL-based scaffold, autograft and PCL-based scaffold alone which consisted of thoracic levels 6-7, 8-9 and 10-11 were biomechanically tested using the following protocol. Normal thoracic spine levels 4-5 and 12-13 were also tested to provide a baseline normal stiffness value for comparison. Tests were performed in flexion/extension, right/left lateral bending and right/left axial rotation sequentially. For each test, loads of 2 Nm were applied under moment control in the positive and negative direction respectively in accordance to previously described literature. [3,4] This constituted one cycle, with each thoracic level undergoing five cycles for each of the three tests and the last cycle being taken for analysis. All tests were conducted within the elastic range and loadings were non-destructive, resulting in a linear load versus deformation response. Stiffness was calculated as the gradient of the regression line fitted to data points that lay between a moment of 1.5 and 2 Nm. To date, all of the sheep at the 6-month time point have been tested (n=6).

Results/Expected Results: In all tests, the BMP levels were shown to have a higher average stiffness and greater range, whilst the autograft level showed the second largest average stiffness (slightly more than the scaffold level). All implanted levels showed an increase in average stiffness over the normal spine levels of 300%, 530% and 330% for scaffold, BMP and autograft respectively. This demonstrates that PCL-based scaffold + rhBMP-2 performs well biomechanically as a bone graft substitute.

Conclusion: The combination of biologics and scaffold engineering represents a novel approach to promoting bony fusion in the setting of thoracic spine deformity correction. Application of computer–controlled extrusion–based additive manufacturing devices pave the way for customization of future spinal bone graft substitutes in the treatment of patients with adolescent idiopathic scoliosis requiring surgical correction and fusion.

References:

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