Proceedings of the International Conference on Biomedical Engineering and Systems
Prague, Czech Republic, August 14-15, 2014
Paper No. 58

An Assessment of Trabecular Bone Architecture Following Balloon Kyphoplasty

Philip Purcell, Fiona McEvoy, Stephen Tiernan
Bioengineering Technology Centre, Institute of Technology Tallaght,
Dublin 24, Ireland
philip.purcell@ittd.ie

Seamus Morris
National Spinal Injuries Unit,
Mater Misericordiae University Hospital,
Eccles St., Dublin 7, Ireland.

Extended Abstract

Balloon Kyphoplasty is a minimally invasive treatment that uses an inflatable balloon to restore the height of collapsed vertebra. The fractured vertebra is subsequently stabilised by low pressure injection of bone-cement into the cavity created by the balloon. While most published studies agree that kyphoplasty is a relatively safe and effective means of achieving pain relief, there is a lack of consensus on its long-term biomechanical implications and association with adjacent level fractures. A clinical study of 175 kyphoplasty patients correlated a 'peri-cement halo' phenomenon on post-operative radiographs with a 78% recollapse rate of the treated level within 2 months of the intervention (Kim et al., (2012)). In-vitro studies of kyphoplasty have found significant height loss of treated vertebra compared to vertebroplasty under cyclical loading and observed cracks propagating from the interface region into the trabecular bone (Kim et al., (2006)). The interface region is of particular interest in kyphoplasty since the trabecular structure is compacted during balloon inflation which impedes cement interdigitation (Purcell et al., (2014)).

The current study utilised high resolution computed tomography data to analyse the distribution and architecture of trabecular bone displaced by the kyphoplasty balloon. Simulated kyphoplasty was performed on porcine L1 vertebra and scanned with an isotropic voxel size of 19µm. A custom image analysis program was used to identify the compacted region by iteratively growing an elliptical region of interest until the bone displaced by the balloon was accounted for in the surrounding region. Opensource software (BoneJ) was used to calculate the architectural properties of the intact and compacted bone regions. Structural anisotropy for the compacted region was also analysed based on fabric tensor eigenvalues.

Analysis of the results found volume fraction and connectivity density increased by 81% and 301% respectively for the compacted region while structural anisotropy decreased. Results from the custom program showed reliable identification of the compaction region and indicated a potential correlation between the bone fabric orientation and compaction distribution.

These findings illustrate the significant structural changes that occur in trabecular bone after kyphoplasty and highlight the need to consider the interface in biomechanical models of the treatment. This data represents a significant step towards the goal of extending computational analyses of kyphoplasty to include the complex micromechanics of the compacted bone-cement interface. Understanding gained from this combined methodology is currently being utilised to evaluate alternative surgical techniques, with the aim of sustaining kyphoplasty height correction over the long-term.

References

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