# *In vitro* evaluation of degenerated intervertebral disc stability following treatment with discoplasty

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***Abstract*—Discoplasty (i.e. injection of acrylic cement inside damaged intervertebral disc) has recently been proposed to treat extreme degenerations. This study investigates the stability of porcine lumbar spines after percutaneous cemented discoplasty as a first insight of human degenerative disc disease treatment. Functional spinal units were mechanically tested in flexion, extension, and lateral bending, up to 5.4 Nm. A Digital Image Correlation system measured the strain over the surface of the specimen, focusing on the strain in the disc surface and in the vertebrae. The behaviour (stiffness, range of motion, strain distribution) was compared in healthy, degenerated and treated conditions. Disc degeneration increased the flexibility and showed larger strains on the disc surface. On the contrary, cement injection inside of the intervertebral disc resulted in a wider strain distribution over the disc while restoring its height.**

***Keywords*—Discoplasty, Intervertebral disc, Spine, Biomechanics, Strain analysis.**

## I. Introduction

LOW back pain can be caused by nerve compression due to stenosis of the foramen associated with intervertebral disc degeneration. Invasive surgical solutions such as interbody fusions can be used to improve the patients' state but cannot be performed on weak patients with comorbidities. A less invasive approach, percutaneous cemented discoplasty (injection of bone cement inside the disc), has been recently developed for the elderly [1]. The mechanical impact on the spine stabilization and surrounding tissues have not been investigated yet.

The aims of this *in vitro* work were to: (i) develop a method to simulate degenerated discs and (ii) test the stabilization of spine segments after discoplasty.

## II. Materials and Method

Porcine lumbar spines (from T13 to L6) were obtained at the slaughter house from 7 healthy young animals. They have been sectioned into 8 Functional Segment Units (FSU) (1 T13-L1, 6 L3-L4, and 1 L5-L6 segments). All the soft tissues around the vertebral bodies were removed, leaving intact the anterior and posterior ligaments, and the facet joints. The FSUs were aligned with the intervertebral disc horizontal; the extremities were potted into acrylic cement following a method already developed [2]. In order to measure surface strains with Digital Image Correlation (DIC), a white speckle pattern of water-based paint was sprayed over the specimens previously stained by a methylene blue solution (Fig. 1).

The specimens were mechanically loaded in presso-flexion, presso-extension, and lateral bending under 5.4Nm (maximum force: 200N). A 1s loading ramp was chosen to mimic *in vivo* motion [3]. After preconditioning, 5 cycles were applied and the 6th was used for result analysis. Disc surface images were recorded at 15 Hz by a 3D-DIC system (Q400, Dantec Dynamics, Denmark). Image analysis was performed with the associated DIC software using optimized parameters in accordance with speckle dot size, camera field of view, and specimen dimensions [4]. The resulting correlations were performed with a facet size of 35 pixels, a grid spacing of 11 pixels and a local regression filter kernel of 19x19 pixels. The displacements and the principal strains were computed [5]. The specimens were tested with the disc in three conditions: the intact disc (INT), after having manually removed the nucleus pulposus (NP) (simulated degenerated condition - DEG), and with acrylic cement injected in place of the NP through the incision performed at the precedent step (discoplasty - DP).

The Range Of Motion (ROM) of the FSUs was also measured at the peak load.

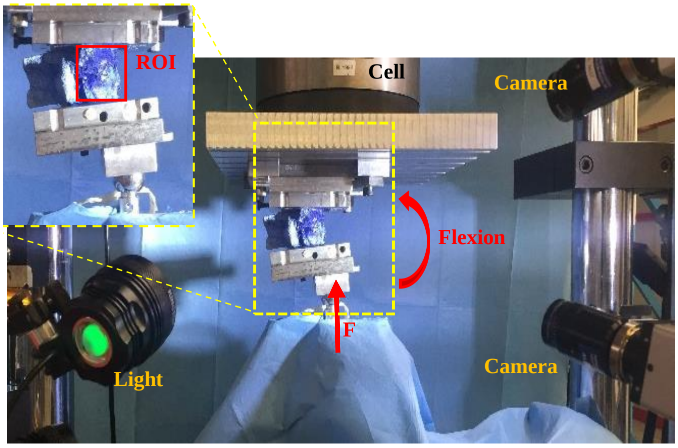


Fig. 1: Experimental set-up for spine testing in presso-flexion. The Region of Interest (ROI) of DIC is located around the IVD.

## III. Results & Discussion

Correlations and measurements were successfully performed for all loading configurations and all the conditions of the disc. For all motions, disc degeneration increased the ROM (by 50% in flexion, 90% in extension and 7% in lateral bending) while discoplasty constrained it (120%, 60%, and 60% of the intact condition respectively). The disc height has been restored by discoplasty, thus restoring the width of the foramens. While removal of the NP increased the flexibility of the specimen, discoplasty restored the range of motion since the cement tensed the fibres around as the NP was stretching the AF in an intact disc. Vertebra motion was more affected by degeneration in flexion and lateral bending. By studying the relative displacement between the 2 vertebrae during a cycle, vertical displacement was more affected by disc degeneration in lateral bending and flexion. Discoplasty was associated with a vertical relative translation similar to INT and DEG cases except in lateral bending which reached more than 5 times the intact case. This could be explained by a reduced cement amount in the bending side since the cement was injected from the opposite lateral side. Thus, less cement would allow more vertical relative displacement of the vertebra. More investigations are going on to confirm this hypothesis. The discs underwent large deformations, with different strain distribution between INT, DEG, and DP (Fig. 2). Maximum and minimum principal strains were respectively oriented horizontally and vertically over the disc without any variation of direction according the disc state. However, the condition of the spine impacted the values of the strain. Degenerated disc exhibited the largest strains. This is consistent with the increase of specimen range of motion. Indeed, in an intact disc, the NP has the role of tensor and puts the fibers of AF under pressure whereas in case of degeneration, only the AF remains, leaving a larger range of displacement for the fibres and thus larger strains. Cement injection resulted in a wider strain range over the disc, with a mean around -50000 microstrain for the min principal strain, and some strain peaks that were different from the intact disc.

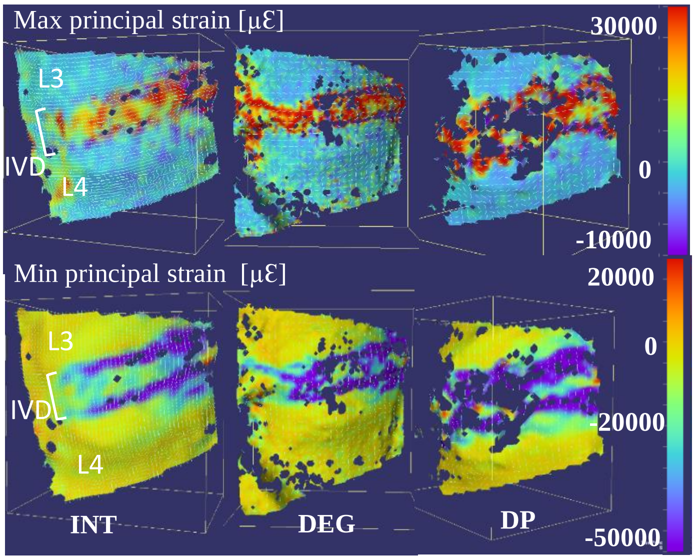


Fig. 2: Strain distribution during presso-flexion on intervertebral disc surface (lateral view) in intact (INT), without NP (DEG), and cemented (DP) conditions for max (up) and min (down) principal strains.

## IV. Conclusion

These preliminary tests have demonstrated remarkable differences before and after the discoplasty both in terms of segment flexibility, and in terms of distribution of strains on the annulus fibrosus. Degenerated disc presented the largest strains in the annulus due to the lack of tension of the fibres and after discoplasty the disc height was restored which should be converted in a relief of pain for the patient. Indeed, by filling the inner disc, discoplasty reproduces the nucleus role and tenses the fibers of the annulus in a similar way. Thus, the specimens after discoplasty have a flexibility closer to intact condition. However, abnormal results can occur due to the cement distribution inside of the disc or the injection site. The variability of the segment geometry is also to consider when comparing the results. Further tests will allow to confirm the observed trends and to establish the statistical significance of the results. The strain measurement by means of DIC will allow detecting if discoplasty is inducing any concerning strain concentration on the remaining intervertebral disc.

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