Introduction: Disc displacement of intervertebral discs (IVD) is a direct parameter of the outer annular strain distribution and an indirect parameter of the internal stress of the disc. It was assumed that spinal defects are seen by a larger disc bulging first [1]. This would also account for disc protrusion, prolapse and its standard treatment meaning nucleotomy. Since an optical disc displacement acquisition needs a free sight to the IVD, the posterolateral region is hardly accessible. This region is known to be of high clinical relevance, because it is the frequent region for disc prolapse causing painful nerve root compression. The purpose of the work was to firstly measure three-dimensional disc displacements at different specimen conditions and to use these data to validate a finite element (FE) model, which can be taken to study the non-accessible posterior and posterolateral regions. A further aim of was to investigate whether a nucleotomy of an else intact segment increases posterolateral disc displacement.

Materials and Methods: A non-contact laser scanning method was developed conducting three-dimensional surface scans of intervertebral discs [2] (Fig. 1). This system was especially designed to fit in a spine tester [6]. The working principle of the laser scanner relies on rotating the laser displacement sensor (OWLF4007, Welotec, Germany) about the specimen. Surfaces were obtained from the undeformed and deformed situation and disc displacements were determined by computing the scalar distance to the closest neighbor on the corresponding surface [3].

Spinall specimens (n=6) were mounted in the spine tester [6] and forced by pure moments of ±7.5 Nm to move in flexion/extension, lateral bending and axial rotation. The biomechanical testing was performed on intact specimens first. Subsequently, specimens were reduced in their structures yielding both vertebral bodies with the isolated disc (i.IVD) without all spinal ligaments, facet joints and the vertebral arches.

An extensively validated FE-model [4] was taken to mimic the both in-vitro tested situations (intact and i.IVD). Disc displacement data of both in-vitro conditions were taken to evaluate the predictability of the FE-model. A load combination linking 5.3 Nm axial rotation with 5.3 Nm lateral bending plus 1000 N axial preload was applied to the FE-model. This combination of the load vectors yielded 7.5 Nm towards the resulting motion direction. This combination is known to yield highest tensile fiber strain in the disc [5]. This situation was also computed for the else intact segment, but with nucleotomy.

Results: Color maps were generated from in-vitro surface scans yielding detailed information about the disc displacement and its location dependency for i.IVD state (Fig. 2). The FE-model was compared with these data. For all load directions, mean deviations were 0.21 mm, 0.18 mm, 0.19 mm and 0.37 mm for the anterior, lateral, posterolateral and posterior regions, respectively. Largest deviation was seen at the posterior region for flexion, which was 0.71 mm.

Discussion: This study included several biomechanical tasks, since it was hardly possible to directly assess dorsal disc displacement on intact specimens during in-vitro measurements. Therefore, we employed a combination of different novel methods including IVD surface scans and FE-model simulation. We think that the results could be possible explanation why surgical nucleus restoration after nucleotomy might be advantageous. With the here presented methodology we are able to evaluate three-dimensional disc displacement as an additional parameter in spine mechanics. In future, this measurement setup can be used to evaluate nucleus replacement implants to proof whether they are able to restore after nucleotomy the physiological contour and deformation of the healthy disc.

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References: