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Original article

The effect of posterior non-fusion instrumentation on segmental shear loading of the lumbar spine

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ABSTRACT

Background: Lumbar stenosis and facet osteoarthritis represent indications for decompression and instrumentation. It is unclear if degenerative spondylolisthesis grade I with a remaining disc height could be an indication for non-fusion instrumentation. The purpose of this study was to determine the influence of a mobile pedicle screw based device on lumbar segmental shear loading, thus simulating the condition of spondylolisthesis.
Materials and methods: Six human cadaver specimens were tested in 3 configurations: intact L4–L5 segment, then facetectomy plus undercutting laminectomy, then instrumentation with lesion. A static axial compression of 400 N was applied to the lumbar segment and anterior displacements of L4 on L5 were measured for posterior-anterior shear forces from 0 to 200 N. The slope of the loading curve was assessed to determine shear stiffness.
Results: Homogenous load-displacement curves were obtained for all specimens. The average intact anterior displacement was 1.2 mm. After lesion, the displacement increased by 0.6 mm compared to intact ($P = 0.032$). The instrumentation decreased the displacement by 0.5 mm compared to lesion ($P = 0.046$). The stiffness's were: 162 N/mm for intact, 106 N/mm for lesion, 148 N/mm for instrumentation. The difference was not significant between instrumented and intact segments ($P = 0.591$).
Conclusions: Facetectomy plus undercutting laminectomy decreases segmental shear stiffness and increases anterior translational L4–L5 displacement. Shear stiffness of the instrumented segment is higher with the device and anterior displacements under shear loading are similar to the intact spine. This condition could theoretically be interesting for the simulation of non-fusion instrumentation in degenerative spondylolisthesis.

1. Introduction

Lumbar non-fusion instrumentation systems are aimed to reduce the risk of adjacent segment degeneration secondary to fusion [1]. Total disc replacement can be efficiently indicated in low-back pain caused by discopathy. Nevertheless, the load-sharing complex between the disc and facet joints may lead to recidivating pain if additional moderate facet degeneration is not diagnosed preoperatively [2]. This has spawned an interest in the development of posterior facet preserving non-fusion systems, which may decrease segmental motion without suppressing it [3–5]. Facet resurfacing and replacement devices have been designed to address severe facet osteoarthritis and subsequent stenosis [6].

Instrumentation is required after facetectomy or arthrectomy because of segmental increase of motion in axial rotation and under shear loading [7,8]. *In vitro* studies and finite element models indicate that posterior non-fusion devices could stabilize a lumbar segment and maintain mobility after partial or total facet resection and laminectomy [9–12]. First clinical trials showed that decompression and non-fusion instrumentation might improve back- and leg-pain, and the quality of life in degenerative spondylolisthesis [13–15]. However, these devices are restricted to segments with a sufficient disc height, and it is not clear to what extent

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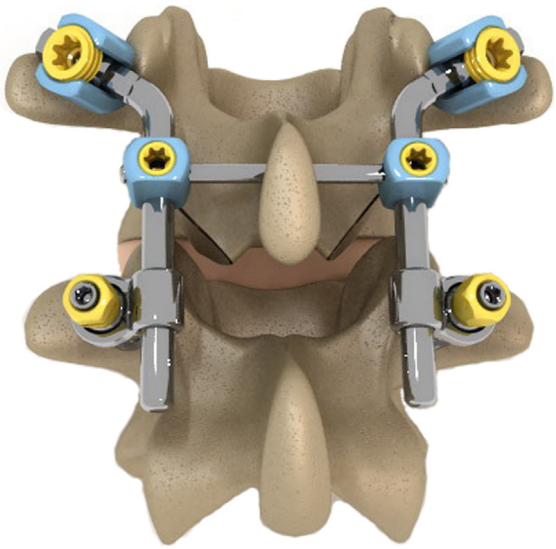

Fig. 1. Non-fusion instrumentation with polyaxial connector linking the rods to caudal screws, thus allowing a three-dimensional movement and stabilization after medial facet resection.

decompression should be performed, since shear forces are transmitted through the implant, which may lead to device-related complications [16].

The NeoFacet^{TM} (Clariance, Dainville, France) represents an implant, which is designed for posterior element supplementation if a facet resection is required in addition to undercutting laminectomy. It might be indicated for low-back pain, mainly due to facet osteoarthritis, and sciatica due to lateral recess and/or foraminal stenosis. This system utilizes four pedicle screws with two angulated rods fixed cranially. This implant is made of implantable grade metal components, which address the anatomical requirements of the segments L3–L4 and L4–L5. Traditional pedicle screw fixation is used. Two rods (30° or 45°) are inserted and fixed at the cranial vertebra using polyaxial pedicle screws. These rods are linked to caudal pedicle screws using a polyaxial connector on each side, which allows movements in flexion-extension, lateral bending and axial rotation. A cross-link connects both rods to each other, thus avoiding excessive axial rotation (Fig. 1). Pedicle screws are manufactured of titanium alloy. A titanium plasma spray coating is applied to the bone interface surfaces of the screws. The other components of the implant are manufactured from a wear-resistant cobalt-chromium-molybdenum alloy.

A previous *in vitro* study demonstrated that this device could preserve flexibility between lumbar vertebrae while restraining motion in axial rotation after facetectomy [17]. It is also important to investigate the shear behavior of this implant, which may be indicated in degenerative spondylolisthesis grade I with a remaining disc height. The purpose of this study was to determine the influence of non-fusion instrumentation on a lumbar segment under shear loading, thus simulating the conditions of degenerative spondylolisthesis treated by facetectomy plus undercutting laminectomy.

2. Materials and methods

Six fresh-frozen human cadaveric L4–L5 spine segments were tested. The average age of the donors was 73.8 years and ranged from 63 to 84 years. There were 5 males and 1 female. The specimens were freshly dissected, sealed in double plastic bags, frozen, and stored at −20 °C until testing. The specimens were thawed to 6 °C 12 to 14 hours before starting the preparation process. Soft tissues were removed, leaving all ligaments, joint capsules, discs and bony structures intact. Spinal deformities, damage or severe degeneration of the discs and facet joints were excluded macroscopically and radiographically. Median disc heights were ≥ 7 mm on lateral radiographs. The experiment was performed at room temperature, while using a saline solution (NaCl 0.9%) to moisture the disc.

The cranial half of the L4 vertebral body and the caudal half of the L5 vertebral body were embedded in 2 metal containers using polymethylmetacrylate cement (Technovit 3040; Haerus, Hanau, Germany). The median plane of the L4–L5 disc was aligned with an anterior inclination of 10° with regard to the horizontal plane, thus reproducing its sagittal alignment *in vivo*. Biplane radiographs were used to check the orientation of the specimen. Shear loading tests were conducted in a specific spine-testing device that was designed for this purpose. The caudal container, fixed on L5, was rigidly screwed to a table, while the cranial container, fixed on L4, was mounted to a rail, allowing translation in the sagittal plane. A compressive preload of 400 N was applied to the motion segment [10,11,18,19]. Loads were applied to L4 using dead weights placed at the end of loading bars, cables and pulleys, thus inducing an anterior translation of L4 on L5 (Figs. 2 and 3). This system

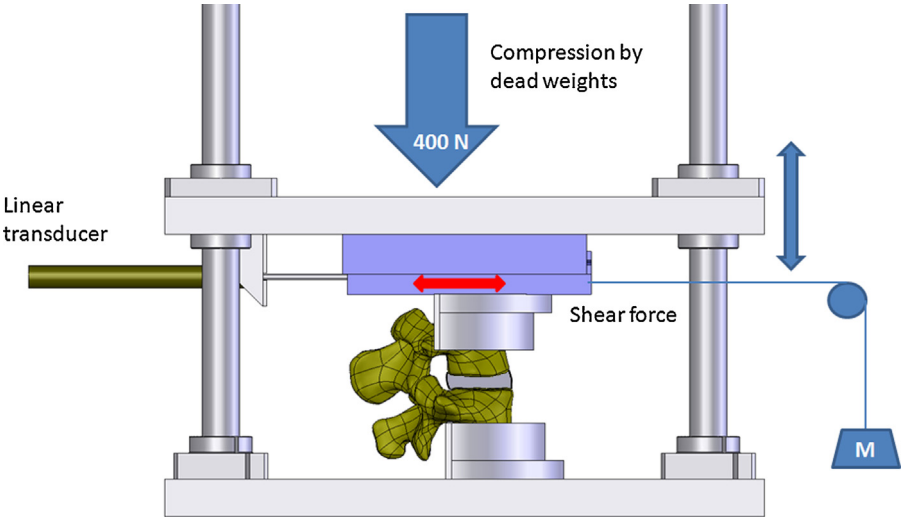

Fig. 2. Experimental setup for *in vitro* shear testing of the L4–L5 segment, with a mobile rail fixed to L4, a linear transducer for measurements of translation of L4 on L5 obtained by anterior traction via a cable and pulley system attached to the rail.