Effect of Axial Load on the Flexural Properties of an Elastomeric Total Disc Replacement

INTRODUCTION:
Recently, Total Disc Replacement (TDR) implants, used to replace degenerative intervertebral discs, have been developed, that consist of elastomeric components. These elastomeric implants, attempt to provide motion properties that resemble those of the natural disc. Unlike previous articulating TDR implants, elastomeric devices provide the opportunity to restore axial stiffness and flexural stiffness characteristics; however, little is understood about how the flexural properties of these implants may change under different axial compressive loads. In the natural spine, there is an increase in flexural stiffness and reduction in range of motion with increasing axial load, resulting in a more “stable” motion segment. It was anticipated that elastomeric TDR devices would exhibit similar characteristics. The aim of this investigation was to quantify the change in flexural properties of an elastomeric TDR device (Cadisc™-L) when subjected to increasing magnitudes of axial load.

MATERIALS AND METHODS:
Six Cadisc™-L lumbar devices (MC-10mm-9° size) were supplied by Ranier Technology Limited, Cambridge, UK. The devices were supplied in closed plastic containers and pre-hydrated in physiological saline solution. In the laboratory, the devices were stored in their containers and placed in a water bath at 37 °C until required for testing. Platens, with the footprint of the device, were used to secure the devices for mechanical testing, with the additional use of dental cement (WHW Plastics, Hull, HU8 7BF, UK). The devices were placed into a Perspex bath on the testing machine and secured with screws. The bath was filled with Ringer’s solution, maintained at 37 °C during testing.

Experimental testing was carried out on a Bose® spinal disc testing machine controlled with WinTest Software (Bose Corporation, ElectroForce Systems Group, Minnesota, USA). At the start of the test, a static load of 500 N was applied to a device. The testing was then programmed to move the device from:

a) 0° to 6° flexion and then back to 0°, at a rate of 0.5 °/s
b) 0° to 3° extension and then back to 0°, at a rate of 0.5 °/s, as recommended by BS ISO 18192-1-4.

The same procedure was repeated at compressive loads of 1000 N, 1500 N and 2000 N. The load, displacement, flexion or extension angle and torque were recorded for each loading regime. Graphs of torque against flexion or extension angle and of flexural stiffness against load were plotted.

RESULTS:
Figure 1 shows the variation of torque with flexion and extension angle for the different compressive loads applied to the Cadisc™-L MC-10mm-9° implant. The torque response increases linearly with flexion and extension angles at 1000 N and higher loads. Figure 2 shows the change in implant stiffness; the flexural stiffness of the implant increases with increasing load in both flexion and extension motions.

DISCUSSION:
Elastomeric TDR devices for the treatment of chronic back pain are intended to provide mechanical properties that more closely approximate those of the natural disc, than earlier designs. Measurements on natural intervertebral discs have shown that discs that were loaded under a pure bending moment between 3-10 N.m achieved flexion angles between 5-15°. The results presented here show the Cadisc™-L implant to be within this range, particularly when subjected to the higher compressive loads. The change in flexural stiffness of the Cadisc™-L implant also approximates the changes observed within the lumbar spine. The results of the present study demonstrate that the flexural stiffness of the Cadisc™-L implant increases with increasing load. Flexural stiffness increases approximately by a factor of 3 between 500 N and 1500 N for flexion and extension respectively. These changes are in keeping with changes observed within the natural lumbar spine. Patwardhan et al. found an increase in the stiffness properties of the natural disc in forward flexion between axial preloads of 400 N and 1200 N. An increase in stiffness was also noted by Stokes et al. and Janevic et al.

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REFERENCES: