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Biomechanical comparison of a two-level anterior discectomy and a one-level corpectomy, combined with fusion and anterior plate reconstruction in the cervical spine

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ABSTRACT

Background: Common fusion techniques for cervical degenerative diseases include two-level anterior discectomy and fusion and one-level corpectomy and fusion. The aim of the study was to compare *via in-vitro* biomechanical testing the effects of a two-level anterior discectomy and fusion and a one-level corpectomy and fusion, with anterior plate reconstruction.
Methods: Seven fresh frozen human cadaveric spines (C3–T1) were dissected from posterior musculature, preserving the integrity of ligaments and intervertebral discs. Initial biomechanical testing consisted of no-axial preload and 2 Nm in flexion-extension, lateral bending and axial rotation. Thereafter, discectomies were performed at C4–5 and C5–6 levels, then two interbody cages and an anterior C4–C5–C6 plate was implanted. The flexibility tests were repeated and followed by C5 corpectomy and C4–C6 plate reconstruction. Biomechanical testing was performed again and statistical comparisons among the means of range of motion and axial rotation energy loss were investigated.
Findings: The two-level cage-plate construct had significantly lower range of motion than the one-level corpectomy-plate construct ($P \leq 0.03$). Axial rotation energy loss was significantly ($P \leq 0.03$) greater for the corpectomy-plate construct than for the two-level cage-plate construct and the intact condition.
Interpretation: A two-level cage-plate construct provides greater stability in flexion, extension and lateral bending motions when compared to a one-level corpectomy-plate construct. A two-level cage-plate is more likely to maintain axial balance by reducing the energy lost in axial rotation.

1. Introduction

Two-level cervical degenerative disease is a common condition in clinical practice and two treatments for this condition are: two-level anterior cervical discectomy and fusion (ACDF) and one-level anterior cervical corpectomy and fusion (ACCF). ACCF is a preferable procedure when the spinal cord compression is located behind the vertebral body (Goldberg and Hilibrand, 2003; Pickett et al., 2008), especially when ossification is present (Hwang et al., 2007). Alternatively, ACDF is preferable when the primary lesion is at the disc level (Goldberg and Hilibrand, 2003). Patients are often categorized in a “gray zone” where the superiority of the clinical outcomes of one procedure with respect to the other is difficult to determine. The ambiguity between treatments creates a debate on the clinical impact and superiority.

Several pathological factors should be considered for selecting the most appropriate surgical procedure, such as the extent and location of the spinal cord compression and pre-existing cervical deformities (Fraser and Hartl, 2007; Papadopoulos et al., 2006). However, investigations on the biomechanical performance between the two conditions under specific *in vitro* scenarios can also provide substantial information. For example, a stable construct is believed to have greater chance of successful bony fusion and less likelihood of hardware migration or dislodgement. In other words, changes in range of motion (RoM) can be interpreted in terms of possible instability and the amount of energy lost (estimated from a load-displacement curve) can also provide information about the likelihood of maintaining a “corrected” balance after surgery. Thus, including biomechanical factors into the evaluation can help spine surgeons decide between two or more possible surgical treatments.

The main rationale for corpectomy is to reduce the number of fusion surfaces but, to our knowledge, no conclusive evidence supports that the incidence of nonunion is higher in a 2-level ACDF than in a 1-level

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ACCF. Advantages of the discectomy and osteophytectomy are: simpler technique, shorter operative time, less blood loss and ability to incorporate the intervening vertebral body into the fusion construct. Advantages of corpectomy include: better decompression, especially in cases where cord compression is present posterior to the vertebral body (*i.e.* soft disc migration, ossification of posterior longitudinal ligament or kyphotic deformity with the spinal cord draping over vertebral body), ability to harvest autologous bone from corpectomy, and less fusion surfaces. To complement the characterization of these treatments, the aim of this investigation was to biomechanically compare ACDF and ACCF, with anterior plate reconstruction, through *in vitro* testing by observing overall motion and axial rotation plasticity (axial-rotation energy loss).

2. Methods

2.1. Specimen preparation

Seven (7) fresh frozen human cadaveric spines (C3–T1, 3 females and 4 males, average age was 49.7 years) with no history of spinal pathology or trauma were used in this study. Specimens were thawed overnight in a refrigerator at 40 F prior to dissection. All adipose tissue and musculature were dissected and care was taken to preserve all ligaments, joint capsules, discs, and osseous structures. Each cervical specimen was fixed by installing self-tapping screws in the most superior and most inferior segments (C3 and T1 respectively). The end segments and screws were potted in custom potting frames using polyester resin (Bondo, Bondo Corp, Atlanta, GA, USA). When not mounted in the test apparatus, specimens were kept moist by gauze saturated in 0.9% saline solution to prevent desiccation. The testing sequence allowed each specimen to be unfrozen for a maximum of forty-eight (48) hours.

2.2. Biomechanical testing

Custom potting frames were used to attach the specimens to a custom mechanical testing and simulation apparatus affixed to a two axis (axial translation and rotation) servohydraulic testing machine (MTS 858 MiniBionix modified by Instron, USA). The specimens were loaded with 0 N of axial preload and 2 Nm of torque in flexion/extension (FE), left/right lateral bending (LB) and left/right axial rotation (AR), following the same protocol as Setzer et al. (2012). No preload was implemented to effectively measure the specimen under pure moments. Axial rotation load was applied dynamically at 0.125 Hz by the servohydraulic system while FE and LB were manually loaded/unloaded by adding/removing a 3 kg mass in a pulley system with a radius of 6.8 cm. Axial rotation loads were controlled by a bi-axial load cell (Dynacell, Instron 1KN axial, 25 Nm torque) and all loads were under 8% of maximal torque. The zero torque (0 Nm) position, prior to loading, was considered the neutral position and used as the datum for all flexibility tests.

Angular displacements (0.1° of accuracy) were recorded by an Optotrak data acquisition system (Optotrak 3020, Northern Digital, Inc., Waterloo, Canada). Angles were calculated from infrared light emitting diode sensors that were affixed to the frame. Euler angles were derived from the marker positions which were referenced on a single global coordinate system. Data acquisition rate was 10 Hz and was recorded for 10 s.

2.3. Implant insertion

Each specimen was initially tested under intact condition as a control measurement. Discectomies were performed at C4–5 and C5–6 levels, followed by a reconstruction with 5 × 14 mm PEEK cages (CONSTRUX® Mini PEEK Spacer System Orthofix, Texas, USA) and anterior cervical plate (Reliant™ Anterior Cervical Plating System Orthofix, Texas, USA) from C4 to C6. The intervening C5 level was also incorporated into the fusion. 4.4 × 14 mm self-drilling/self tapping primary bone screws (Reliant™ Anterior Cervical Plating System Orthofix, Texas, USA) were used at the top and bottom of construct with the same size but fixed angle screws at C5. The biomechanical testing was performed according to the protocol (described above), then screws, plate and cages were removed and C5 corpectomy was performed. The second stabilization was performed with corpectomy cage (NCage™ 4-lobe Orthofix, Texas, USA) and anterior plate from C4 to C6. The variability in the vertebral heights required the corpectomy cages to range from 24 × 14 mm to 29 × 14 mm depending on the size of the defect, as it is seen in clinical practice. The plate system used in the ACCF construct was the same as in the ACDF construct, but 4.75 × 14 mm self tapping "rescue" bone screws (Reliant™ Anterior Cervical Plating System Orthofix, Texas, USA) were used to achieve sufficient purchase when being installed in the previous screw site. Fig. 1 shows the specimen's set-up in the testing machine.

2.4. Analysis

The primary measurements for this study were RoM and axial rotation energy loss. RoM was calculated from the total displacement during simulated motions of flexion/extension, lateral bending and axial rotation. Axial rotation energy loss was calculated by trapezoidal numerical integration of the hysteresis loop in axial rotation. Energy loss was not evaluated for flexion/extension and lateral bending motions since the manual loading of the single torque step did not allow accurate estimation of a load-displacement curve for computing the energy lost in the aforementioned motions.

Due to the non-normal distribution nature of the data, statistical analysis was performed using a non-parametric Friedman test (Le Huec et al., 2002) for RoM in each motion, as well as energy loss in axial rotation. When significant differences were found at a 0.05 level, *post hoc* Wilcoxon signed-rank tests were performed to determine significant differences among conditions.

3. Results

The medians and ranges of all results are summarized in Table 1. All RoM of the fusion constructs were compared to the intact condition and the medians are as follows: ACDF significantly reduced FE by 38%, LB by 17% and AR by 28%, while ACCF slightly (no significant) decreased FE by 10%, LB by 3% and AR by 18% (Fig. 2). The greater restriction in all motions offered by the ACDF construct was significantly different than that of the ACCF condition (Table 2).

In terms of the hysteresis loop (energy loss) for AR, only the ACCF condition showed significantly larger lost when compared to the intact condition, being this increased even significantly different than that of the ACDF condition. Median AR energy loss decreased by 6% and increased by 30% in the ACDF and ACCF respectively with respect to the intact condition. A representation of the AR hysteresis loops for the

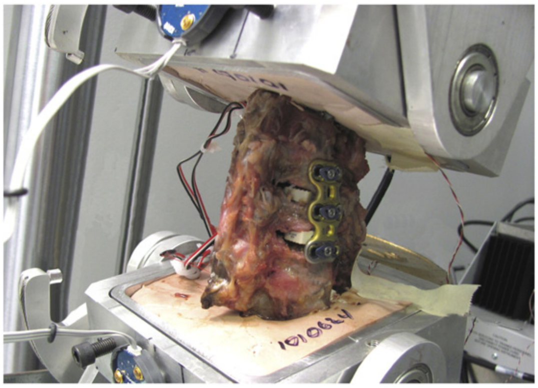

Fig. 1. C3–T1 spinal segment after the two-level anterior discectomy and fusion (ACDF) treatment under lateral bending flexibility test (left loading).