ALTERED HUMAN FACET CAPSULE STRAINS SUBSEQUENT TO ANTERIOR LUMBAR INTERBODY FIXATION

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ABSTRACT

In cases of low back pain (LBP) associated with biomechanical lumbar instability, anterior interbody fixation can be used as a surgical treatment, but its subsequent affect on facet joint capsule strains during physiological spine motion is unknown. The purpose of this study was to evaluate the changes in strains on the lumbar facet joint capsules at the level of and adjacent to a single level L_{4-5} antero-lateral interbody fixation. Using a displacement controlled apparatus, lumbar spine specimens were potted and actuated during physiologic motions of extension, flexion, left lateral bending and right lateral bending, while the developed moment, vertebral angle and facet capsule strains were recorded. Specimens were then plated at the L_{4-5} level, and retested. Fixation resulted in an increase in mean moment at the three vertebral levels for all motions. There was also an increase in intervertebral angle at L_{3-4} and L_5-S_1, and a decrease in intervertebral angle at L_{4-5} for all motions. Plane strains in the L_{3-4} and L_5-S_1 facet capsules increased as a result of the fixation. L_{4-5} facet capsules experienced decreased and increased strains ipsilateral and contralateral, respectively, to the side of fixation. Increased capsular strains, if supra-threshold for capsule nociceptors, could play a role in persistent LBP following interbody fixation.

METHODS

Unembalmed, human, ligamentous lumbar spine specimens (n = 7) were potted and actuated under displacement control at the T_{12} vertebral level. The T_{12} body was connected to a rod via a rigid U-shaped coupling with a pin through the middle of the vertebrae allowing a single degree of freedom. The coupling was in series with a force transducer mounted to a linear actuator by a low friction universal joint. Thus, as the spine was actuated, loads were applied without inducing a moment at the point of application.

Spines were tested in flexion (F), extension (E), left lateral bending (LB), and right lateral bending (RB) (10 cycles at displacements of 10 – 40 mm at 10mm/s). Biaxial inclinometers mounted on adjacent vertebrae measured vertebral body rotations for determination of intervertebral angulation (IVA). Capsule plane strains (Lagrangian large strain formulation) were measured by optically tracking, with two CCD cameras, the displacements of infrared reflective markers (1 mm radius) glued to capsule surfaces. Markers were typically placed as 3 x 3 arrays forming four quadrilaterals, from which plane and principal strains were calculated relative to the neutral vertical position of the spine. To account for rotation of the plane, an extension of the method of Hoffman and Grigg (1984) was used. Principal strains E1 and E2 (whose orientations were closest to the X- and Y-axis, respectively) were organized as maximum (predominantly tensile) and minimum (predominantly compressive) strains, defined as $\overline{E1}$ and $\overline{E2}$, respectively. Data were obtained before and after in-vitro simulation of single-level L_{4-5} anterior interbody fixation using Synthes® Anterior Thoraco-Lumbar Plates (ATLP) screwed on to the left anterolateral aspects of the specimens (two interbody screws per vertebra). Differences in IVA and moments that occurred as a result of spinal fixation at the L_{4-5} joint level were compared at each tested displacement for each motion using ANOVA (alpha = 0.05). Displacement relationships with IVA, moment and strain at a given joint level were compared before and after spinal fixation using Comparison of Linear Regression Lines (CLRL, alpha = 0.05).

RESULTS

Fixation at L_{4-5} resulted in an increase in mean moment at all vertebral levels for all motions, though not all increases were significant (Fig. 1A-C). During E and F, the greatest increase in moment occurred at L_{4-5}, while L_5-S_1 exhibited the greatest change during bending. The relationship between moment and displacement was highly correlated at all vertebral levels during all motions for both the normal and plated specimens. This relationship was statistically different between the normal and plated states during bending trials at all vertebral levels ($p<0.05$).

Plating at the L_{4-5} level resulted in an increase in mean IVA at L_{3-4} and L_5-S_1, and a decrease in mean IVA at L_{4-5} at all

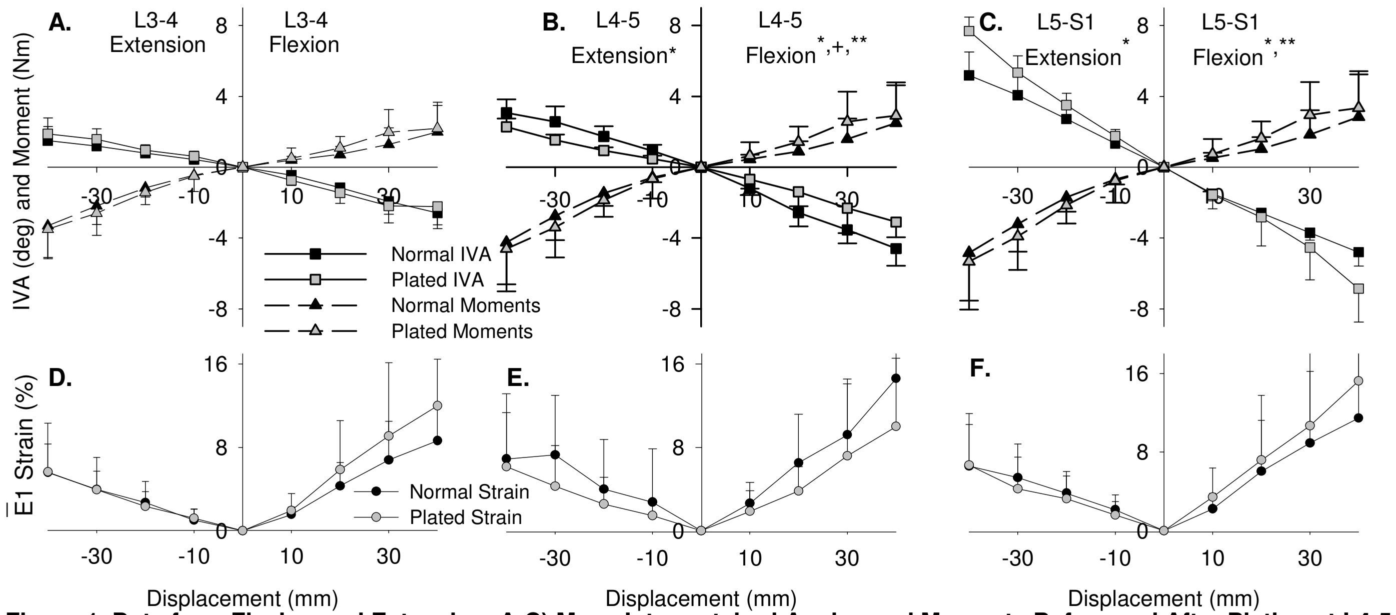

Figure 1. Data from Flexion and Extension. A-C) Mean Intervertebral Angles and Moments Before and After Plating at L4-5. D-F) Left Capsule Mean $\bar{E}1$ Strains Before and After Plating at L4-5. * Sig. between Normal and Plated IVA; +Sig. between Normal and Plated Moments; ** Sig. between Normal and Plated Strains.

displacements for all motions (Fig. 1A-C). Similar to the moment results, the largest percent change in IVA typically occurred at L_{4-5} during E and F and at L_5-S_1 during bending. At L_{4-5}, significant differences between the normal and plated IVAs were observed during E and F (ANOVA, $p<0.05$; CLRL, $p<0.05$). Significant differences in IVA at L_5-S_1 were observed during all four motions (ANOVA, $p<0.05$; CLRL, $p<0.05$). Compared to the changes in IVA at L_{4-5} and L_5-S_1, the changes at L_{3-4} were smaller during all motions.

In the L_{3-4} facet capsules, plane strains were variable and dependent upon the type of motion (Fig. 1D). During F & E, there were no significant differences in mean $\bar{E}1$ or $\bar{E}2$ following fixation. During bending, significant increases in mean $\bar{E}1$ occurred following fixation (CLRL, $p<0.05$), but only for the capsules being stretched (i.e., the right capsule during LB and the left capsule during RB).

In the L_{4-5} facet capsules, spinal fixation resulted in significant alterations in principal strains, which appeared to be influenced by the side on which the ATLP was located (Fig. 1E). Ipsilateral to the instrumentation (left), motions producing tension of the capsule (F and RB) resulted in a decrease in the mean $\bar{E}1$-displacement relationship (CLRL, $p<0.05$). Contralateral to the instrumentation, the changes in $\bar{E}1$-displacement relationships were significant for every motion ($p<0.05$).

In the L_5-S_1 capsules, spinal fixation resulted in non-uniform (left vs. right side) increased strains (Fig. 1F). In the left capsule, tensile motions (F and RB) produced the greatest increase (abs. magnitude) in the mean $\bar{E}1$-displacement relationship ($p<0.05$). The opposite was true for the right capsule, for which the mean $\bar{E}1$-displacement relationship was greater during E and LB ($p<0.05$).

DISCUSSION

In cadaveric lumbar spine specimens, single level, interbody fixation reduced, but did not eliminate, motion at the level of fixation, and on average, increased joint motions (i.e., IVA) above and below the fixation site. Consequent to the joint motion changes, facet capsule strains changed in a similar manner (i.e., increasing & decreasing, respectively). Significant differences in the relationship between strain and displacement were only seen at a vertebral level during motions that had corresponding significant differences in IVA, moments, or both. Assuming in-vivo instrumentation leads to greater fixation (i.e., actual intervertebral fusion), it is reasonable to extrapolate that changes in capsule strains would be even greater than those observed in cadaveric specimens.

Human facet joint capsules are innervated with mechanoreceptors and nociceptors (McLain & Pickar, 1998). Following single body fixation, the increased capsule strains during physiological spine motions could be supra-threshold for capsule nociceptors. In this case, physiological spine motion could lead to LBP. This mechanism may be involved in some cases of surgical ‘failed back syndrome’, as well as in the loss of normal intervertebral motion that is seen in types of non-surgical LBP syndromes, which can be amenable to conservative treatments (exercise, physical therapy, or manipulation).

ACKNOWLEDGEMENTS

Partially funded by NIH (CCR subcontract 5U01AT001701-01) & Dept. of Orthopaedics.

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