Influence Of Graft Size On Spinal Instability With Anterior Cervical Plate Fixation Following In Vitro Flexion-Distraction Injuries

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Introduction: For anterior cervical discectomy and fusion with plating (ACDFP) procedures, the purpose of the bone graft, in addition to promoting bone-on-bone fusion, is to restore disc space height, soft tissue tensioning, and normal spine curvature. Selecting a larger graft may increase stability as a result of restored tension in the ligaments, yet too much distraction decreases the load carried by the facet joints. Too small a graft, on the other hand, can result in pathologic changes to spinal alignment, poor soft tissue tensioning, and the potential for graft prolapse [1]. While graft size is clearly an important surgical factor, it has not been thoroughly investigated from a biomechanical perspective in the context of cervical trauma. Therefore, the objectives of this study were: (1) to determine if graft height significantly alters the kinematic stability (i.e., range of motion, ROM) of ACDFP for a simulated unilateral facet perch (UFP) based on a standardized injury model (SIM); and (2) to examine further changes in ACDFP kinematics following additional simulated unilateral facet fracture (UF#) and bilateral facet dislocation (BFD) injuries. It was hypothesized that ACDFP with an undersized graft would lead to an increased ROM due to poor soft tissue tensioning, while an oversized graft would be more stable due to the opposite effect.

Methods: Eight fresh-frozen cadaveric C4-C7 segments were used (age 76±5 years). The C4-C5 and C6-C7 motion segments were immobilized to isolate the C5-C6 functional unit. Flexibility testing was performed on each specimen using a custom spinal loading simulator modified from a materials testing machine (Instron® 8874, Canton, MA). An Optotrak® Certus™ motion capture system (NDI, Waterloo, ON, Canada) was used, with Optotrak® ‘Smart Markers’ rigidly attached to the C5 and C6 vertebrae. A testing protocol was designed to assess the kinematics of the intact, injured, and instrumented states. First, the intact kinematics were collected for flexion-extension, axial rotation, and lateral bending. The SIM was then induced in the right facet joint at C5-C6 using a previously validated technique [2]. Briefly, this model sectioned both facet capsules, the right ligamentum flavum, and the complete left annulus along with the anterior half of the right annulus (as this level of soft-tissue disruption was commonly observed in our previous dynamic testing [2]), followed by rotating the specimen to a unilateral perched position. The ACDFP testing condition was repeated for three different sized grafts (and correspondingly sized plates) in the following order: (1) measured disc space height, (2) measured disc space height less 2.5mm (i.e., undersized), (3) measured disc space height plus 2.5mm (i.e., oversized). Grafts were machined from Delrin™ plastic into rectangular blocks. After testing the kinematic stability of the ACDFP with the three graft sizes in the SIM (ACDFP:SIM), the same three graft sizes were compared for two additional injury states. These were an additional unilateral facet fracture (ACDFP:SIM+UF#) followed by a bilateral facet dislocation (ACDFP:SIM+UF#+BFD) based on previous evidence for this injury pattern [3]. Kinematic data analyses were performed post-hoc using custom-written LabVIEW™ software to determine C5-C6 ROM. Data were analyzed using two-way repeated measures ANOVA (factors = graft size and injury condition) with post-hoc Student-Newman-Keuls tests (α=0.05).

Results: In terms of the kinematics stability between the intact and injured states, a larger ROM was measured for the SIM compared to the intact state for all applied motions (p<0.05). The largest increase seen was in axial rotation ROM, with an average percent increase of 286% between intact and SIM. The SIM also more than doubled intact ROM in the other two motions, with a 123% in flexion-extension and a 159% increase in lateral bending. ROM analysis of the injury states and graft sizes revealed, in flexion-extension, that there was an effect of both injury (p=0.015) and graft size (p=0.013) (Figure 1). For this motion, the ACDFP:SIM+UF#BFD had a smaller decrease in ROM compared to the other injury states (p<0.05). Further, the oversized graft had a larger decrease in ROM than the other two graft sizes (p<0.05). For axial rotation, there were no overall effects of either injury state (p=0.072) or graft sizes (p=0.135), but there was a significant interaction between these two main effects (p=0.004). One-way ANOVAs were therefore performed and found that in the ACDFP:SIM+UF#BFD state only, the undersized graft had a larger decrease in ROM compared to the other grafts (p>0.05). In the ACDFP:SIM+UF# state, the measured graft had a smaller decrease in ROM than both the undersized and oversized grafts (p<0.05). In the final injury state (ACDFP:SIM+UF#+BFD), the undersized provided a larger decrease than both the measured and oversized grafts.
Discussion: ACDFP is a well-accepted mode of treatment for flexion-distraction injuries [4]; however, there has been little effort to examine the graft size of the instrumented construct for traumatic cervical spine injuries. Based on the current study, interactions observed between the graft sizes and injuries and the variability between the motions suggest that the selection of graft size should consider all these factors. This is evident in the fact that the undersized graft outperformed both the measured height and oversized grafts in lateral bending, while the oversized graft performed better in flexion-extension. One possible explanation for the superior performance of the undersized graft in axial rotation and lateral bending is that, in addition to facet interaction, there was greater uncovertebral joint overlap (i.e., increased contact between adjacent uncinate processes). This would have provided a second bony stabilizer against motion that was not engaged in the measured and oversized grafts [5].

While this study and others have attempted to add clarity to the surgical factor of ideal graft size, there still remains no consensus, particularly in the context of injury. In conclusion, results from this study demonstrate that graft size does affect the biomechanical stability of ACDFP in a unilateral facet injury model; undersizing the graft results in both facet overlap and locking of the uncovertebral joints, providing greater stability in lateral bending and axial rotation, while oversizing the graft provides greater stability in flexion-extension. In the clinical scenario, multiple factors must be considered in graft selection for the stabilization of unilateral facet injuries, including curvature restoration, foramen patency, and construct stability.

Significance: Based on the results of this study, use of an undersized graft, or a graft that engages the uncovertebral joint, may be more advantageous in providing a rigid environment for fusion from an ACDFP procedure, especially if an external collar is being used to limit flexion-extension motion.

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