Biomechanical Analysis of Atlantoaxial Fixation Techniques in an Osteoporotic Cadaver Model

Austin Mike-Mayer, DO[1], Kendrick Lam MD[2], Randal P. Morris, BS[1], Abeer Al Barghouthi, PhD[2], Francesco Travascio, PhD[2,3], Loren L. Latta, PhD[2], Ronald W. Lindsey, MD, FACS[1]
[1]University of Texas Medical Branch, Galveston, [2]Max Biedermann Institute for Biomechanics, Miami Beach, FL, [3]University of Miami, Coral Gables, FL,

abmlonghorn@gmail.com

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INTRODUCTION: Odontoid fractures are among the most common cervical spine fractures in the elderly and are associated with significant morbidity and mortality. Recent evidence suggests improved survival quality of life following surgical stabilization compared to nonoperative treatment. This study seeks to quantify the stability of posterior transarticular screws (Margerl technique) and posterior C1 lateral mass screws with C2 pedicle screw rod fixation (Harms technique) in an osteoporotic odontoid fracture model. It was hypothesized that both posterior trans-articular screws and C1 lateral mass screws with C2 pedicle screw rod fixation will have increased C1-C2 stability in the osteoporotic spine compared to C1-C2 trans-articular screws.

METHODS: Six cadaveric spine specimens extending from the cephalus to C7 were used in this study. The osteoporotic nature of the specimens was confirmed through quantitative CT analysis. Reflective marker arrays were attached to C1 and C2 to measure the movement of each during loading and a marker was attached to a pin in the dens, Figure 1. The testing protocol measured the neutral zone in each principle plane while a Optitrack (NaturalPoint, Inc., Corvallis, OR) motion capture system recorded C1 and C2 motion. C2-C3 and occiput-C1 were allowed to move freely under load. Motions of each spine were recorded after a simulated Type II odontoid fracture and following odontoid fracture stabilization with either 2 cannulated C1-C2 transarticular screws (Margerl technique), or posterior C1 lateral mass screws with C2 pedicle screw rod fixation (Harms technique).

RESULTS SECTION: Motion of the dens, C1 and C2 after fixation were all reduced compared to the fractured condition. Angles between C1 and C2 with fixation averaged 0.62 degrees during flexion-extension neutral zone motion. For transarticular screw fixation, 0.20 degrees; for pedicle screw fixation, 1.04 degrees. Angles between C1 and C2 without fixation averaged 9.76 degrees. The most critical motion to control the dens is axial rotation of C1 over C2. If the dens moves with C1, it can see potential motions of ±80 or more degrees. We could not measure rotation of the dens due to there being only one reflective marker on the dens. But we could calculate the translations of the dens during neutral zone motions, and found that fixation limits motion between the dens and C2 to 0.14 mm average; for transarticular fixation, 0.12 mm; for pedicle screw fixation, 0.15 mm. The motion between the dens and C1 was 0.04 mm with fixation. Without fixation the motion between the dens and C2 averaged 0.74 mm, range 0.23-2.32 mm. The average motion between the dens and C1 was 0.26 mm. Decoupling of the dens from C2 motion led to increased dens movement that was instead coupled with C1 movement in flexion and extension, likely secondary to intact ligamentous structures in the destabilized spines. Both the Margerl and Harms fixation techniques enabled recoupling of this pathologic movement allowing for C1, C2, and the odontoid to move as a relative unit, thus establishing more anatomic stability to the upper cervical spine.

DISCUSSION: This study demonstrates that both that Magerl and Harms posterior fixation techniques decrease motion of the odontoid compared to no-treatment in our osteoporotic bone model as well as allowing coupling of C1-C2 thus potentially allowing a stable environment for C1-C2 fusion. These results suggests both techniques may be suitable for the surgical management of these injuries in geriatric patients, and surgeons should consider factors other than fixation stability when selecting a surgical fixation technique.

SIGNIFICANCE/CLINICAL RELEVANCE: Both the Margerl and Harms cervical fusion fixations can minimize dens motion in Type II odontoid fractures in an osteoporotic cadaveric bone model. Both techniques allow for C1, C2, and the odontoid to move as a relative unit, establishing more anatomic stability to the upper cervical spine.

IMAGES AND TABLES:

Figure 1. Biomechanical setup for C-spine motion capture.