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Biomechanical evaluation of surgical constructs for stabilization of cervical teardrop fractures

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Abstract

BACKGROUND CONTEXT: Cervical flexion teardrop fractures (CFTF) are highly unstable injuries, and the optimal internal fixation construct is not always clearly indicated.
PURPOSE: The purpose of the current study was to determine whether the type of fixation construct (anterior, posterior, or combined) or number of joint levels involved in fixation (one or two) affected the relative stability of a CFTF injury at C5–C6.
STUDY DESIGN/SETTING: Human cadaveric cervical spine specimens were mechanically tested under displacement control in the intact state and after creation of CFTF at C5–C6 with stabilization using five different instrumentation constructs. Joint stiffness and intervertebral translation of the constructs were compared with the intact state and normalized (instrumented/intact) to assess relative differences across the five constructs.
METHODS: Spine specimens were mechanically tested in the intact state during flexion, extension, lateral bending, and axial rotation. CFTF was created at C5–C6 by creating an osteotomy at C5 and transecting the posterior ligaments and intervertebral disc. Specimens were tested with anterior, posterior, and combined single-level constructs (C5–C6). Then, a corpectomy was performed at C5, and specimens were retested with the two-level constructs (C4–C6; anterior and anterior-posterior). Joint stiffness and intervertebral translations were computed.
RESULTS: All five fixation constructs resulted in joint stability that was as good as or better than that of the intact specimens. Relative stiffness of the constructs differed depending upon the motion type considered, though the two-level anterior-posterior construct typically provided the greatest stability. Intervertebral translation along the major axis was reduced the most for both of the combined instrumentation systems, although there were few changes in total intervertebral translation across the five constructs.
CONCLUSIONS: All five constructs restored stability comparable to that of the intact specimens. The significance of the relative differences in constructs for the in vivo spine is unclear and warrants further clinical investigation.

Keywords: Cervical spine; Biomechanical testing; Trauma; Instability; Implant stability; Combined anterior and posterior instrumentation; Anterior instrumentation; Posterior instrumentation

Introduction

The cervical flexion teardrop fracture (CFTF) is a highly unstable, traumatic injury. CFTF is distinguished from other fracture patterns with a teardrop fragment because the inferior aspect of the vertebral body's posterior fragment is displaced posteriorly, disrupting the anterior and posterior ligamentous structures, as well as the

FDA device/drug status: approved for this indication: Medtronic Sofamor Danek Atlantis cervical plates.

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intervertebral disc, at the joint inferior to the injury [1]. In the classification system of Allen et al. [2], CFTFs may be considered as Stage IV or V compressive flexion injuries [1], which comprised 52% of the compressive flexion injuries in the classification study [2]. Mechanisms of injury include shallow diving, motor vehicle accidents, or other trauma [2]. In a clinical study, internal fixation was superior to more conservative treatments (ie, halo thoracic vest) in the restoration of sagittal alignment and minimizing treatment failures [3].

There are a wide variety of options for internal stabilization, though each has its own inherent limitations. Anterior stabilization is the preferred method because decompression can be performed through the same approach, though clinically it can be associated with graft displacement and late development of kyphosis [4]. Posterior fixation typically provides better stability compared with anterior fixation, but presents problems such as patient positioning and damage to posterior structures during surgery [5]. For injuries exhibiting high instability, combined anterior-posterior fixation is sometimes indicated and can provide superior stability, though it presents technical difficulties during surgery and is subject to limitations associated with both anterior and posterior fixation alone [5]. As each technique has its own biomechanical advantages and inherent limitations, the appropriate method of fixation for a given injury pattern is not always clearly indicated.

Damage to the discoligamentous structures of the cervical spine results in increased motion at that joint, particularly during flexion and extension [6]. The goal of any internal instrumentation is to decrease motion at the injury site with the ultimate goal of achieving bony fusion. The effects of fixation in the acute stage have been studied during in vitro biomechanical studies using cadaveric spine specimens. Calf cervical spines were subjected to either posterior or complete discoligamentous injury and then were stabilized using posterior, anterior, or combined fixation systems [7]. The relative stability of the fixation systems depended upon the motion type (axial compression, flexion, extension, or torsion), degree of injury, and number of joint levels involved. In some cases, injury to the sagittal body is so severe that corpectomy and two-level plating are needed. However, there has not been a single study comparing the relative stability of single-level and multilevel fixation systems in a human cadaveric cervical spine model using different approaches (ie, anterior, posterior, or combined).

The purpose of the current study was to assess the stability of five surgical instrumentation systems (single-level: anterior, posterior, and combined; corpectomy: anterior and anterior-posterior) during in vitro physiological motions using human cadaveric cervical spine specimens. It was hypothesized that the stability of the instrumented spine specimens would be as good as or better than that of the intact specimens. It was also hypothesized that relative stability of the constructs would depend upon the type of physiological motion being tested.

Methods

Spine specimens

Unembalmed, cadaveric, human cervical spine specimens (C1–T1; n=11; age 60.2±9.8 years, 7 male, 4 female) were obtained through National Disease Research Interchange (Philadelphia, PA). Specimens were procured within 24 hours postmortem from donors free of spine pathology and shipped frozen to our laboratory. Before testing, specimens were radiographed (anterior-posterior and lateral views) to verify that they were free of bony abnormalities. Cervical spine specimens were prepared by removing superficial tissue, resulting in ''ligamentous'' cervical spine specimens. After dissection, K-wires were inserted into C1 and T1, and specimens were potted at the T1 and C2 vertebral levels using a quick-setting epoxy (Bondo; Bondo Corporation, Atlanta, GA).

Mechanical testing

Intact specimens were tested during physiological motions of flexion, extension, lateral bending, and axial rotation using methods described previously in detail [8]. Briefly, for testing during flexion, extension, and lateral bending, T1 was secured to the testing surface, and a rod with a rigid U-shaped coupling was attached to the epoxy at C2. The U-coupling was connected to a threaded rod that was in series with a force transducer (Model 9363-D1-50-20P1; Revere Transducers, Tustin, CA) and a linear actuator (Model ME3528-406C; Galil, Inc., Rocklin, CA). A single trial during a given motion type consisted of 10 cycles at 10 mm/s to a given peak displacement (Fig. 1, top). For each motion type, a specimen was tested to four peak global displacement magnitudes at C2 (extension: 10, 20, 30, 40 mm; flexion: 20, 30, 40, 50 mm; lateral bending: 10, 20, 30, 40 mm). Peak displacements were determined during preliminary studies as those which produced maximum moments (ie, at C7–T1) less than a predetermined 2.0 Nm torque limit [9]. The 2.0 Nm torque limit was chosen to ensure that the motions tested remained within the physiological range and prevented damage due to plastic deformation. If the torque measurement at a given displacement magnitude approached the 2.0 Nm limit, then the larger peak displacements were not tested. In these cases, smaller peak displacement magnitudes were tested to ensure that a minimum of four peak displacements were included for each motion type.

After testing during flexion, extension, and lateral bending, intact specimens were tested during axial rotation as previously described [10,11]. Briefly, an aluminum plate (12 cm diameter, 0.6 cm thick), which had a 3/4′, 3 cm high, 6-point bolt soldered to its surface, was secured to the epoxy at C2. The plate was in series with a torque sensor (Model TTD400; Futech, Irvine, CA) and torque motor (Model ME2130-198B; Galil, Inc., Rocklin, CA). A single trial consisted of 10 cycles to a peak displacement at 5°/s.