Biomechanical Evaluation of Subcortical versus Bicortical Screw Purchase in Anterior Cervical Plating

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Summary

The purpose of this in vitro study is to compare the stabilities provided by anterior cervical H-plating with screws purchased either subcortically or bicortically on porcine cervical spines. Nine porcine cervical spines (C3–C4) were challenged by 12 Nm in extension followed by 6 Nm in flexion in 6 consecutive steps, i.e., (1) when disc was intact, (2) after discectomy. Subsequently, a tricortical bone graft was inserted to simulate interbody fusion. Each specimen was tested again (3) when plated with 16 mm screws to purchase subcortically and (4) after cyclic loading (f = 0.5 Hz, n = 1000), (5) when plated with 30 mm screws to purchase bicortically and (6) after cyclic loading. Neutral zone and range of motion were parameters normalized for comparison.

The results showed comparable stability in constructs plated with screws purchased either subcortically or bicortically before cyclic loading. Cyclic loading deteriorated construct-bone relation in both groups, yet bicortically purchased screws rendered additional stability in anterior cervical plating.

Keywords: Anterior cervical fusion; biomechanics; cervical plating.

Introduction

Anterior cervical disectomy and interbody fusion, since it was introduced by Robinson and Cloward, has gained increasing popularity for treating a diverse spectrum of cervical spinal disorders [6, 20]. When this technique was applied to treat patients with single-level cervical spondylotic myelopathy or disc herniation, satisfactory results with fusion rate of 74%–98% and a graft extrusion rate of 2.1%–4.6% were reported [22]. Comparatively, when this technique was utilized to treat patients with spinal trauma or spanned more than two disc levels where the bone grafts cannot be held securely, the incidence of graft extrusion and late deformity became unacceptably high, as high as 10.2%–29% and 38%–64%, respectively [22]. To solve this, various screw-plate systems were designed and applied clinically to facilitate anterior cervical fusion. Caspar trapezial plate and Synthes H-plate were the two systems which have achieved widespread clinical use in recent years [4, 22]. Biomechanical evaluations showed anterior cervical plating in conjunction with interbody fusion could provide additional stability to the spine not only in flexion-extension but also in lateral bending and axial rotation [21]. Nevertheless, controversies still existed regarding the optimal purchase depth of screws in anterior cervical plating. Since the incidence of significant hardware loosening was reported to be approximately 5% and dysphagia had been related to late screw migration [2, 12] some investigators held it an absolute necessity to engage the screws bicortically [1, 4, 13, 17, 18, 24], while others believed subcortical screw purchase can be equally effective [2, 3, 12], so that the technical reluctance and the potential risk of neurological injury can be eliminated. The purpose of this study is to evaluate biomechanically the possible advantage of bicortically purchased screws against wobbling elicited by flexion-extension movement in anterior cervical plating.

Materials and Methods

Preparation of the Specimens

Porcine cervical spines (C2–C5) were harvested fresh and carefully dissected to remove nonligamentous supporting soft tissue, part of the C3 and C4 vertebrae were fixed and mounted into resin bases so that flexion-extension motions of these specimens were
from MTS electrohydraulic piston, a 20-cm aluminum bar, as the designed cart (25 X 10 X 2 cm) bolted to the load cell of the MTS mounting. These mounted specimens were fixed to a specially the sagittal diameters of C5 vertebrae were measured before testing in a high humidity environment. A total of 162 separate biomechanical tests were performed on 9 porcine cervical FSUs [5]. The distance from the center of the disc to the top of the mounting was carefully adjusted to 10 cm for each specimen, θ represents angular deformation

Testing Procedures

To select appropriate length of screws for subsequent fixation, the sagittal diameters of C5 vertebrae were measured before mounting. These mounted specimens were fixed to a specially designed cart (25 X 10 X 2 cm) bolted to the load cell of the MTS (Bionex 858, MTS system Corp.). To deliver the load generated from MTS electrohydraulic piston, a 20-cm aluminum bar, as the lever arm, was connected in one end to the top of the mounted specimen along the mid-sagittal plane and in the other confined the MTS piston to a roller connector, so the length of the lever arm could be set as 15 cm by adjusting the position of specimens along the railroad on the testing cart. As a result, the loads generated from the MTS piston can be converted to flexion-extension moments on the tested specimen by the following equation: Moment (Nm) = Load (N) × Lever arm (m). To better conceptualize the response to these moments, the angular deformations of FSUs were calculated from the following equation:

\[ Y = \frac{A - B \tan(\theta/2)}{2} \tan \theta \]

Here θ represents angular deformation of FSU, Y represents the displacement of MTS piston recorded by an x-y recorder, A represents the length of the lever arm (15 cm), and B represents the distance from the center of rotation to the top of the mounting (10 cm) (Fig. 1).

Specimens were tested by gradual increments of compression load from 0 to 40 newton (N) followed by distraction load to 80 N. Pilot studies showed excessive challenge of screw-bone interfaces never happened if the specimens were loaded within this range. As a result, the moments applied on the specimens were equivalent to 12 Nm in extension and 6 Nm in flexion, angular deformation of FSUs under flexion as well as extension were calculated separately. These procedures were sequentially conducted on each specimen under 6 different conditions, i.e., when (1) disc was intact (inact), (2) disc, anterior longitudinal ligament, and posterior longitudinal ligament were cut with a scalpel (cut). Subsequently, the injured disc was removed, and a tricortical graft taken from the porcine ilium was snugly inserted into the disc space to simulate interbody fusion of Smith-Robinson procedure [20]. The next step was to fix cervical H-plate of Synthes on each FSU with 2 sets of 3.5 mm cortical screws of different lengths driven from the holes in the plate into the tract on the C3 or C4 vertebrae prepared previously with a drill. As the anteroposterior diameter of C4 ranged from 23.3–27.8 mm, we used 16 mm screws for subcortical purchase and 30 mm screws for bicortical purchase through the same screw tracts. For each specimen, purchase depth was double checked with a lateral radiograph before testing. Tests were subsequently performed when (3) plating with 16 mm screws to purchase subcortically (SP), (4) repeated (3) after cyclic loading (SPc). Cyclic loading was applied in this study by loading the specimens 4 Nm in extension and 2 Nm in flexion repeatedly with the frequency 0.5 Hz for 1000 times. (5) Plating with 30 mm screws to purchase bicortically (BP), these 30 mm screws were carefully applied along the same tracts to replace the 16 mm ones. (6) repeat (5) after cyclic loading (BPc). For each testing step, three load-deformation curves were recorded with an interval of 30 seconds to allow for creep (Fig. 2).

The resultant load-deformation curves were angular deformation of the intervertebral joint yielded to flexion-extension moment. These curves were by no means linear but presented sigmoid appearances [5]. As neutral zone (NZ) represents the joint laxity around the neutral position, it was defined as the deformation between the neutral position and the initiation point of spinal resistance to physiological motion [19]. In this study we found initial resistance usually occurred if 0.75 Nm of flexion-extension moment was given, reflected by the abrupt change of slopes in load-deformation curves (Fig. 2). Range of motion (ROM) was defined as the difference between the two points of physiological movement. In this study it was the summation of angular deforma-