EFFECTS OF CROSS-LINK CONFIGURATIONS ON ROD STABILITY IN TORSION

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Introduction:
The clinical success associated with spinal fusion is related to the mechanical stability provided by the applied instrumentation. Although sagittal plane stiffness is significantly enhanced with these systems, they are susceptible to instability under lateral bending and torsional loading conditions. The torsional stiffness of bilateral rod constructs has been augmented with the advent of cross link devices. While increasing lateral bending stiffness, the effect of cross links is predominately seen during torsional loading. Though the cross-linkage mechanisms provide increased resistance to both lateral bending and torsional loading, it remains unclear as to the cross-link configuration which yields the most stable construct. In this study, the authors evaluated the effects of a pedicle screw-rod system with various cross-link configurations under torsional loading. The authors hypothesize that, with respect to the other transverse cross-link systems, the diagonal cross-link configuration will provide the greatest torsional stiffness.

Materials and Methods:
Eight porcine thoracic segments from skeletally mature specimens weighing from 70-80kg were utilized. Test segments consisted of embedded T10 and T4 levels with 6.5 x 40mm conical pedicle screws (Osteonics Corporation, Allendale, NJ) inserted bilaterally at T9, T8, T6 and T5. A complete corpectomy including the intervertebral disc was performed at the T7 level. Each configuration: Rod-Only (RO, Fig. 1A), Rod-Rod (RR, Fig. 1B), Screw-Screw (SS, Fig. 1C) and Diagonal cross-link (DX, Fig. 1D) was made in order to incorporate the connecting rods. The conical screws tapered 20%, from 7.5 mm at the hub, (major diameter), to 6.0 mm at tip with a thread pitch and depth of 1.8 mm and 1.2 mm respectively. The screw entry point was selected in accordance with the parameters established by Weinstein et al. with minor modification to accommodate the porcine vertebra. Minor rotational adjustments were then made in order to incorporate the connecting rods. Embedding of the proximal and distal vertebral bodies was performed using an alignmenframe and secured with polymethylmethacrylate (PMMA). The embedded specimen was then mounted to a double axle universal joint which reduces external bending, thus generating a pure torsion moment at the proximal end of the specimen. Each construct was repeatedly loaded six times at a rate of 0.2/°s to a torsional load of 3Nm using a materials testing machine (MTS Systems, Eden Prairie, MN).

For each construct, torsional stiffness, energy expended and rotation required to achieve 3Nm of torsional load were computed for cycles five and six. The average of the respective parameters for each construct were analyzed using a Newman-Keuls Repeated Measures Analysis of Variance.

Results:
There was no evidence of mechanical yield or compromise of the specimens throughout the testing regimen of the constructs. The transverse cross-link configurations did not significantly alter the torsional stiffness with respect to the Rod-Only (RO) configuration. The Diagonal cross-link (DX) configuration displayed significantly increased torsional stiffness with respect to all other configurations tested (RO - p<0.01, RR & SS - p<0.05) (Fig. 2). No significant differences were detected among the RO and cross-link configurations tested for the energy expended and rotation required to achieve a 3 Nm torsional load.

Discussion:
Torsional rigidity in spinal constructs can be enhanced with the addition of cross-linking members. In the case of a diagonal cross-link configuration a similarly applied load would place the proximal cross-link member in compression while placing the distal cross-link member in tension. The result is an inherently more stable structure with respect to the use of transverse cross-link configurations. For both energy expended and rotation to achieve 3Nm of torsional load there was a decreasing trend from RO, RR, SS, DX. Although not statistically significant, for both energy expended and rotation, the DX configuration provided the lowest value for the respective parameter. To fully obtain the mechanical performance of these systems, tests involving failure loads would be required.

The authors conclude that a diagonal cross-link configuration provides increased torsional rigidity with respect to conventional transverse cross-link configurations.

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Fig. 1. Illustration of the cross-link configurations evaluated. A. Rod-Only (RO), B. Rod-Rod (RR), C. Screw-Screw (SS) and D. Diagonal cross-link (DX).

Fig. 2. The Diagonal cross-link (DX) configuration displayed significantly increased torsional stiffness.