Screw Implantation Technique Alters the Stability of Cervical Spine Following Anterior Plate Fixation: A Comparative Finite Element Study

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Introduction: Anterior cervical plate (ACP) has been used for fixation of an unstable spine since 1970. Surgeons secure plates to the vertebral bodies using uni-cortical and bi-cortical screws. However, there are reports documenting screw back-out leading to unsatisfactory bony union [1, 2]. A new tri-cortical method of screw implantation for anterior cervical interbody fixation may hold the plate firmly with a tricortical purchase and thus, providing a better stability. The purpose of this study was to evaluate the biomechanical performance of this alternative approach, compared to other standard methods.

Methods: The validated intact (Fig.1a[3]) model was modified to simulate iliac crest cancellous bone graft and ACP system, designed in Solidworks™, at C5-C6 level and the graft was secured using the tri-cortical approach (Fig.1b). The superior screw was placed tricortically at an angle of 35º with respect to the plate and the inferior screw was placed bicortically at 20º angle with respect to the plate (Fig.1e&f). The intact model was also modified to create another model (Fig.1c). This model simulated a single level Atlantis ACP system (Medtronic, Inc.) with four uni-cortical screws (Fig.1d). Appropriate material properties, contacts and boundary conditions were defined for all the models. A compressive follower load of 73.5N and a moment of 1.5 Nm were applied to simulate physiologically relevant motions.
Results:
Fig.2 (i) illustrates the implanted level motion in both tricortical (TCS) and Medtronic ACP systems, compared to the intact. In extension, TCS provided 20% more reduction in motion, compared to Medtronic system. In all other modes, TCS performed equivalent to the Medtronic. At C4-C5 and C6-C7 levels, all the rotations were similar to intact in both the cases. Maximum endplate stresses at the implanted level were greater in TCS (~100MPa).

Fig.2 (ii) depicts the stress distribution on unicortical, bicortical and tricortical screws. Maximum screw stresses were found in the uni-cortical (~430MPa) compared to bi-cortical (~275MPa) & tricortical (~100MPa). Also, uni-cortical screw had the maximum pull out force in axial rotation (140.9 N in LR & 130 N in RR) than other two types of screws.
Figure 2 (i) Angular displacement (degrees) at C5-C6 level in intact and implanted spines for 75 N preload and 1.5 Nm moment.

Figure 2 (ii) von Mises stress distribution on (a) Tricortical (lowest peak stress value) (b) Bicortical and (c) Unicortical screws (highest peak stress value) for 75N preload and 1.5 Nm moment.

Discussion and conclusions: The tri-cortical system induced higher endplate stresses at the implanted level which may enhance the fusion process. Tri-cortical screw had the lowest stresses and least pull out force. Thus screw back-outs/loosening/breakage is less likely to occur for the tri-cortical system, compared to the uni-cortical and bi-cortical system.

References: