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Development of a Finite Element Model of the Upper Cervical Spine to Evaluate the Atlantoaxial Fixation Techniques

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Abstract : The instability in the atlantoaxial joint may occur due to cervical surgery, congenital anomalies, and trauma. There are different types of fixation techniques proposed for restoring the stability and preventing harmful neurological deterioration. Application of the screw constructs has become a popular alternative to the older techniques for stabilizing the joint. The main difference between the various screw constructs is the type of the screw which can be lateral mass screw, pedicle screw, transarticular screw, and translaminar screw. The aim of this paper is to study the effect of three popular screw constructs fixation techniques on the biomechanics of the atlantoaxial joint using the finite element (FE) method. A three-dimensional FE model of the upper cervical spine including the skull, C1 and C2 vertebrae, and groups of the existing ligaments were developed. The accurate geometry of the model was obtained from the CT data of a 35-year old male. Three screw constructs were designed to compare; Magerl transarticular screw (TA-Screw), Goel-Harms lateral mass screw and pedicle screw (LM-Screw and Pedicle-Screw), and Wright lateral mass screw and translaminar screw (LM-Screw and TL-Screw). Pure moments were applied to the model in the three main planes; flexion (Flex), extension (Ext), axial rotation (AR) and lateral bending (LB). The range of motion (ROM) of C0-C1 and C1-C2 segments for the implanted FE models are compared to the intact FE model and the in vitro study of Panjabi (1988). The Magerl technique showed less effect on the ROM of C0-C1 than the other two techniques in sagittal plane. In lateral bending and axial rotation, the Goel-Harms and Wright techniques showed less effect on the ROM of C0-C1 than the Magerl technique. The Magerl technique has the highest fusion rate as 99% in all loading directions for the C1-C2 segment. The Wright technique has the lowest fusion rate in LB as 79%. The three techniques resulted in the same fusion rate in extension loading as 99%. The maximum stress for the Magerl technique is the lowest in all load direction compared to other two techniques. The maximum stress in all direction was 234 Mpa and occurred in flexion with the Wright technique. The maximum stress for the Goel-Harms and Wright techniques occurred in lateral mass screw. The ROM obtained from the FE results support this idea that the fusion rate of the Magerl is more than 99%. Moreover, the maximum stress occurred in each screw constructs proves the less failure possibility for the Magerl technique. Another advantage of the Magerl technique is the less number of components compared to other techniques using screw constructs. Despite the benefits of the Magerl technique, there are drawbacks to using this method such as reduction of the C1 and C2 before screw placement. Therefore, other fixation methods such as Goel-Harms and Wright techniques find the solution for the drawbacks of the Magerl technique by adding screws separately to C1 and C2. The FE model implanted with the Wright technique showed the highest maximum stress almost in all load direction.

Keywords : cervical spine, finite element model, atlantoaxial, fixation technique
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