Miniature Robotic Guidance for Improved Accuracy in C1-C2 Transarticular Screws

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GENERAL: Miniature robotic technology may help reduce the incidence of sizing and malpositioning problems by enabling pre-operative planning of implant size and optimal position, and intra-operative robotic guidance for precise implant placement.

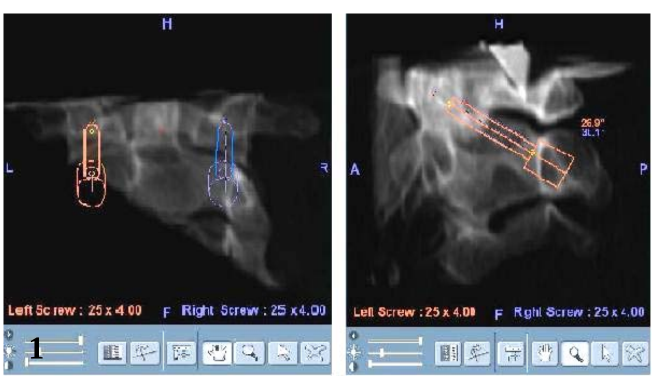
BACKGROUND CONTEXT: The C1-C2 transarticular screw construct is biomechanically robust, achieves long-term fusion rates approaching 100%, and preserves relatively normal motion at the C1-C2 junction. The osseous and vascular anatomy in this region is subject to variation. The placement of C1-C2 transarticular screws is technically challenging, due to the osseous and vascular anatomy in this region, and image guidance has been advocated to improve placement accuracy and reduce risk of errant screw placement. Robotic guidance technology may help reduce the incidence of screw sizing errors and screw malposition.

PURPOSE: The purpose of this study was to evaluate the efficacy of a miniature robotic guidance in improving C1-C2 screw targeting and placement and to explore the placement of C1-C2 screws by a percutaneous technique. The author presents a novel concept for accurate and precise C1-C2 screw placement.

STUDY SETTING AND METHODS: A miniature robotic guidance system (SpineAssist®, Mazor Surgical Technologies, Caesarea, Israel) has been in clinical use successfully for over three years in the thoracic, lumbar and sacral spine. The system has recently been adapted to applications in the cervical spine, in particular C1-C2 transarticular instrumentation. The planning software (Figure 1 – Planning), the CT-to-Fluoro image registration algorithm and the robot-mounting apparatus (Figure 2 – Execution) have been modified and tested in pre-clinical cadaveric studies. Pre-procedural CT scans were performed and presented as a 3D model of the spine, on which the surgeon performed pre-operative planning – determining desired screw sizes and positions. The software supports various measurements of anatomical structures and deformities, as aid to proper sizing and positioning. Intra-procedurally, two fluoroscopic images were taken (AP and 60°-Oblique) and automatically matched to the CT data. The miniature robotic device was then attached to a bed-mounted frame, with a small clamp anchoring to the spinous process of C7, and accurately guided us to the pre-planned entry points and trajectories. Pilot-holes were drilled and k-wires were inserted. Post-procedural CT scans verified accuracy of the placements.

RESULTS: During over 300 clinical cases world-wide, in the thoracic, lumbar and sacral spine, the system has been proven to achieve 98% to 99.5% accuracy rates in various studies, to within 1.2mm of a pre-operatively planned trajectory. It was also shown to reduce fluoro utilization and radiation exposure to the surgeon by an order of magnitude, and to maintain or slightly reduce operative time. Its efficacy has been established for open as well as MIS and percutaneous approaches. Cadaveric studies with the cervical application verified the image processing algorithm, the bed-mounted frame and the overall accuracy of the system for C1-C2 trans-articular screw placements.

CONCLUSIONS: The literature strongly supports that screw sizing and positioning are key to maximizing favorable results of C1-C2 transarticular fusions and avoiding complications and/or revision surgeries. Miniature robotic technology may help reduce the incidence of sizing and malpositioning problems by enabling pre-operative planning of implant size and optimal position, and intra-operative robotic guidance for optimized implant placement.



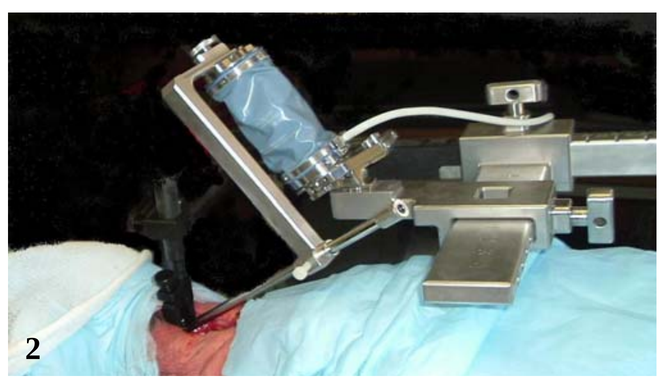


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Figure: (1) Planning screws placement for C1-C2. (2) The SpineAssist robotic device executing the surgeon's plan and guiding the surgeon to the planned location and trajectory.