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Semi-Autonomous Surgical Robot for Pedicle Screw Insertion on ex vivo Bovine Bone: Improved Workflow and Real-Time Process Monitoring

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Abstract : Over the past three decades, surgical robotic systems have demonstrated their ability to improve surgical outcomes. The LBR Med is a collaborative robotic arm that is meant to work with a surgeon to streamline surgical workflow. It has 7 degrees of freedom and thus can be easily oriented. Position and torque sensors at each joint allow it to maintain a position accuracy of 150 µm with real-time force and torque feedback, making it ideal for complex surgical procedures. Spinal fusion procedures involve the placement of as many as 20 pedicle screws, requiring a great deal of accuracy due to proximity to the spinal canal and surrounding vessels. Any deviation from intended path can lead to major surgical complications. Assistive surgical robotic systems are meant to serve as collaborative devices easing the workload of the surgeon, thereby improving pedicle screw placement by mitigating fatigue related inaccuracies. Moreover, robotic spinal systems have shown marked improvements over conventional freehanded techniques in both screw placement accuracy and fusion quality and have greatly reduced the need for screw revision, intraoperatively and post-operatively. However, current assistive spinal fusion robots, such as the ROSA Spine, are limited in functionality to positioning surgical instruments. While they offer a small degree of improvement in pedicle screw placement accuracy, they do not alleviate surgeon fatigue, nor do they provide real-time force and torque feedback during screw insertion. We propose a semi-autonomous surgical robot workflow for spinal fusion where the surgeon guides the robot to its initial position and orientation, and the robot drives the pedicle screw accurately into the vertebra. Here, we demonstrate feasibility by inserting pedicle screws into ex-vivo bovine rib bone. The robot monitors position, force and torque with respect to predefined values selected by the surgeon to ensure the highest possible spinal fusion quality. The workflow alleviates the strain on the surgeon by having the robot perform the screw placement while the ability to monitor the process in real-time keeps the surgeon in the system loop. The approach we have taken in terms of level autonomy for the robot reflects its ability to safely collaborate with the surgeon in the operating room without external navigation systems.

Keywords : ex vivo bovine bone, pedicle screw, surgical robot, surgical workflow
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