



Case Series

Pedicle Screw With Increased Cortical Purchase Can Be Inserted With Same Accuracy as the Screw in Straightforward Trajectory Using 3D Modeling Landmarks

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Abstract

Study Design: Comparison, in terms of insertion accuracy and biomechanical performance, between an increased cortical purchase and straightforward pedicle screw trajectory.

Objective: This study aims to compare a trajectory with increased cortical purchase to the more common straightforward trajectory in terms of strength and insertion accuracy using real-time navigation.

Summary of Background Data: In previous studies, it was suggested that pedicle screw pullout strength is strongly correlated with bone mineral density, and using a more cortical tract allows a greater portion of the denser bone, the cortex, to be in contact with the screw. In light of this advantage, an insertion technique has been proposed more recently, to increase the cortical purchase to maximize screw thread contact with cortical bone. It is performed inserting the screw with reduced transverse inclination and results in cortical bone purchase in the lateral portion of the pedicle.

Methods: Eight T1 and eight T3 vertebra models were reconstructed in Mimics Suite (Materialise, Leuven, Belgium) using CT data obtained with a Medtronic O-arm. Using a previously developed computer algorithm, we calculated all achievable safe trajectories for pedicle screw placement ensuring a minimal distance of 0.5 mm between screw and pedicle edges. For both vertebrae, among these, the straightest and the most convergent trajectories with the calculated insertion region greater than 15% of the total were selected to safely instrument the vertebrae, respectively, as ICP and straightforward techniques. The straightforward technique was planned with a transverse angle of 22.50° in both vertebrae whereas the ICP was planned with a transverse angle of 12.50° for T1 and 2.5° for T3. The screws were implanted by a surgeon experienced in straightforward insertion, and other independent investigators measured placement accuracy and mechanical performance.

Results: The transverse screw angles for T1 and T3 with straightforward technique had average values of 24.93° ± 2.96° and 23.53° ± 2.70°, respectively. For the ICP technique, the average values were 15.60° ± 2.95° for T1 and 2.29° ± 1.55° for T3. The resultant errors associated with screw placement for T1 and T3 were not significantly different ($p > .05$). The pullout failure loads with straightforward techniques ranged from 756 ± 164 N in T1 to 703 ± 74 N in T3 and were not significantly different ($p > .05$) from the values of 699 ± 84 N for T1 and of 732 ± 113 N measured for the ICP.

Conclusions: For the upper thoracic vertebrae tested, despite the use of shorter screws, the insertion technique with increased cortical purchase, in biomechanical terms, is comparable with the straightforward trajectory. Using guidance, the proposed ICP technique was performed with the same accuracy as the popular straightforward technique.

Level of Evidence: Level V.

Keywords: Thoracic instrumentation; Pedicle screws; Cortical purchase; Straightforward; Pullout strength

Author disclosures: none.

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Introduction

Pedicle screw placement is a technique used for a wide variety of spinal procedures. Though the purpose of the procedure is to correct or improve an individual's current spinal ailment, there are drawbacks to pedicle screw placement that have the potential to bring the patient more

detriment than value [1–3]. Neurologic, arthritic, and infectious complications are a few of note, along with fixation failure as a result of screw pullout [4–7].

Breach rates must be taken into consideration when discussing pedicle screw placement. It was found previously that pedicle screw placements had higher breach rates in higher vertebrae levels [8,9]. It has also been reported that breaches can occur in upwards of 40% of pedicle screws in place [10,11]. Efforts to minimize complications and make surgeries less invasive have resulted in much advancement in surgical techniques and technologies.

In current surgical practice, there are mainly two insertion techniques used. The anatomical trajectory is defined as being parallel to the anatomical axis of the pedicle. The straightforward trajectory has been defined as having its sagittal trajectory parallel to the superior endplate of the vertebral body [12,13]. In a study comparing anatomical and straightforward trajectories in thoracic vertebrae, it was found that there was a 39% greater maximum insertional torque and 27% greater pullout strength for the straightforward trajectory compared to the anatomical trajectory [12]. Analysis of different pedicle screw insertion angles has determined that straight screw insertion led to a pedicle-screw construct with better fatigue performance. It was also proposed that a straighter angle of insertion is clinically more practical because it does not require as extensive dissection, or excision, of paraspinal muscles to achieve screw insertion. The mentioned study also suggested that the technique of straight pedicle screw insertion is probably more widely used than reported [14].

In previous studies, it was suggested that pedicle screw pullout strength is strongly correlated with bone mineral density [15,16] and that use of a more cortical tract allows a greater portion of the denser bone, the cortex, to be in contact with the screw [17]. In light of this advantage, more recently, the increased cortical purchase (ICP) trajectory has been proposed as an insertion technique to maximize screw thread contact with the cortical bone [18].

This trajectory is defined as having null convergence in the transverse plane and the cranial direction in the sagittal plane targeting the posterior third of the superior endplate [18]. Since it was first proposed in 2009, many studies have shown the value of the ICP trajectory in terms of pullout strength, the torque, and its potential to be less invasive [19–21]. Recent studies in lumbar and thoracic vertebra have shown an increase in pullout strength and insertional torque associated with ICP trajectory when compared to a traditional trajectory [18,19]. More precisely, a 53.8% increase in insertional torque compared to the traditional trajectory in T9–T12 vertebra has been found [18].

Many different technologies [22–25] have been developed in an effort to reduce the breach rates [10], the time taken to place screws [26], or the need to reposition the pedicle screw [27]. A study found that the use of guidance increased the accuracy of percutaneous pedicle

screw placement by 58% [28]. These findings suggest that difficulties in accuracy of thoracic screw placement may be overcome with the use of appropriate technologies; furthermore, when screws are placed with the assistance of such technology, there may be a decrease in breach rates and pedicle fracture, which was found to correlate with screw thread and pedicle endosteal diameter [28,29].

The precision in pedicle screw placement achieved with real-time navigation creates the opportunity for trajectories optimized for mechanical performance. The aim of the current study was to determine if the ICP is biomechanically more efficient than the straightforward trajectory in the upper thoracic vertebrae. We also explore if using real-time navigation, a pedicle screw trajectory with ICP can be inserted with the same accuracy as the straightforward trajectory. The findings of this study could help provide insight into the pedicle screw placement with ICP trajectory in the upper thoracic vertebrae.

Materials and Methods

Materials

Eight T1 and eight T3 models made of cortical shell inclusive of cancellous inner material (Pacific Research Laboratories, Vashon, WA) were used over cadaveric specimens to reduce experimental variability caused by geometrical and density variations. In accordance with the ASTM F1839 standard, we used models made of grade 20 rigid polyurethane foam that mimics the mechanical properties of human bone to perform mechanical tests using orthopaedic instruments. As specified, the cortical bone of the adopted model was characterized by a density of $320.4 \text{ kg/m}^3 \pm 10\%$ with required minimal and maximal pullout forces of 770 N and 1310 N measured according to the ASTM F543 standard.

Screw placement planning

Volumes identifying cortical and cancellous bone of the vertebrae were reconstructed in Mimics Suite (Materialise, Leuven, Belgium) using CT data obtained with a Medtronic O-arm (Medtronic Navigation, Louisville, CO) at 45 kV and 10 mA with a pixel size of 0.415 mm and thickness of 0.833 mm. Each reconstructed vertebra was processed using a previously developed algorithm in Rhinoceros 3D (Robert McNeel & Associates, Seattle, WA) that calculates all achievable safe trajectories for pedicle screw placement ensuring a minimal distance of 0.5 mm between screw and pedicle edges. The safe trajectories are grouped in increments of 5° in the transversal angle (see Fig. 1A), and for each group the following parameters are calculated: screw length, average sagittal angle $\bar{\alpha}_s$ with its range $\Delta\alpha_s$ (see Fig. 1B), amplitudes Δ_s and Δ_t of the insertion region (see Fig. 1C), and percentage

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