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Tools and techniques

Pedicle screws with modular head vs. preassembled head used in cortical bone trajectory: Can pars and pedicle fractures be prevented in osteoporotic bone?

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ABSTRACT

Pars and pedicle fractures as a result of CBT (cortical bone trajectory) during pedicle screw placement have been reported. The primary aim of the study is to compare the fracture rate between screws with modular heads to screws with standard pre-assembled tulip heads. The secondary aim of the study is to determine the potential variables that can be identified prior to instrumentation in order to predict risk of fractures. Twenty-four fresh frozen lumbar vertebrae were obtained from five different cadavers. Anatomical landmark measurements were obtained. Right and left pedicles of each vertebra were randomly instrumented with the preassembled head screws (n = 24) and modular head screws (n = 24) under video recording. X-ray images were obtained for measuring relative angle deviations between tapped and final screw trajectories. Finally, pullout tests were performed. Seventeen out of twenty-four (70.8%) of the spinous processes had to be excised in order to obtain proper trajectories. Six fractures occurred with pre-assembled head screws versus one in the modular head screws ($p = 0.04$). Distances from the midline to the medial wall of the pedicle were marginally significant as a predictor for fracture ($p = 0.08$). The pullout loads between both types of screws were not statistically different ($p = 0.38$). Age was better correlated with pullout load than absolute bone density value ($p < 0.001$).

In conclusion, modular head screws had a significantly lower fracture rate than pre-assembled head screws for cortical bone trajectory in osteoporotic bone. There was no clear anatomic variable that could be measured pre-operatively to predict potential fracture risk in CBT.

1. Introduction

Cortical bone trajectory (CBT) technique for pedicle screw placement in the lumbar spine has become popular since its introduction in 2009 by Santoni [1]. There are unique factors which makes the CBT technique favorable over the standard pedicle screw trajectory: Increased screw purchase within cortical bone and reduced surgical dissection with minimal invasive approach [2–4]. Engaging more cortical bone during screw insertion poses CBT technique as an attractive procedure for treatment of spine patients who have metabolic bone disease. Several biomechanical studies [1,5–11] and an in vivo insertional torque study [12] were able to demonstrate comparable pullout, cyclic fatigue strength between CBT and traditional pedicle screw technique. Similarly, some clinical studies [2,13,14] showed comparable clinical outcomes between these two techniques.

In contrary to these favorable results, in a biomechanical study, Akpolat et al. [15] showed better fatigue performance with traditional pedicle screw trajectory in vertebrae with compromised bone quality. Additionally, in clinical studies by Glennie et al. [16] and Patel et al. [17], researchers reported screw loosening as a complication associated with CBT. Interestingly, Cheng et al. [18] demonstrated in a cadaveric video-based study that the pars and pedicle fractures, which might occur intra- or post-operatively, could be a possible mechanism for loosening associated with CBT technique. The authors revealed that the tulip head of the pedicle screws were impinging against the base of spinous process and causing iatrogenic fracture during the final screw insertion.

This study was designed to answer the question whether the rate of fracture could be reduced if the head of the pedicle screw was eliminated during the screw insertion. Therefore, the first

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aim of this study was to compare the complication rates of the standard screw with pre-assembled tulip head and the modular screw, of which the head could be attached after screw shank insertion (Fig. 1). Specific parameters studied were:

1. Surgical
   a. Rate of pars and pedicle fracture
   b. Angle deviation comparing tapped trajectory to final screw trajectory.
2. Biomechanical
   a. Pull-out strength after screw insertion

The second aim of the study was to determine the potential factors that could be measured prior to instrumentation, which could be used to predict risk of fractures.

1. Anatomic
   a. Laminar width
   b. Pedicle width
   c. Spinous process height and length
   d. Midline to medial boarder of pedicle distance
   e. Laminar slope
   f. Vertebral levels
2. Bone density and age

Our hypotheses were that the risk of fracture could be reduced using modular head and, secondly, that anatomic and bone quality-related variables could predict pars fracture.

2. Material and method

2.1. Study design

In this cadaveric study, two different types of CBT screws (with modular heads and with preassembled heads) were instrumented on either pedicle of the same vertebra. Anatomic measurements and bone density analysis were performed prior to instrumentation. Outcome measures were:

a. Visually detected fracture
b. Pullout load
c. Radiographic angle deviation from original trajectory after final screw insertion.

2.2. Specimen preparation

Cadavers with previous procedures on the lumbar spine, infectious history, and neoplastic disease were excluded. Five human cadaveric lumbar spines were obtained. To quantify the bone mineral density, Dual-Energy X-ray Absorptiometry (DEXA) scans (Hologic Discover, Marlborough, MA) were obtained. The lumbar spines were separated into single levels and all the soft tissues were removed. Then, each vertebra was placed into heat-sealed plastic bags and stored at −20 °C. The specimens were placed into a fridge to thaw-out approximately sixteen hours prior to experiment. A total twenty-four of vertebrae were used for this study (N = 24).

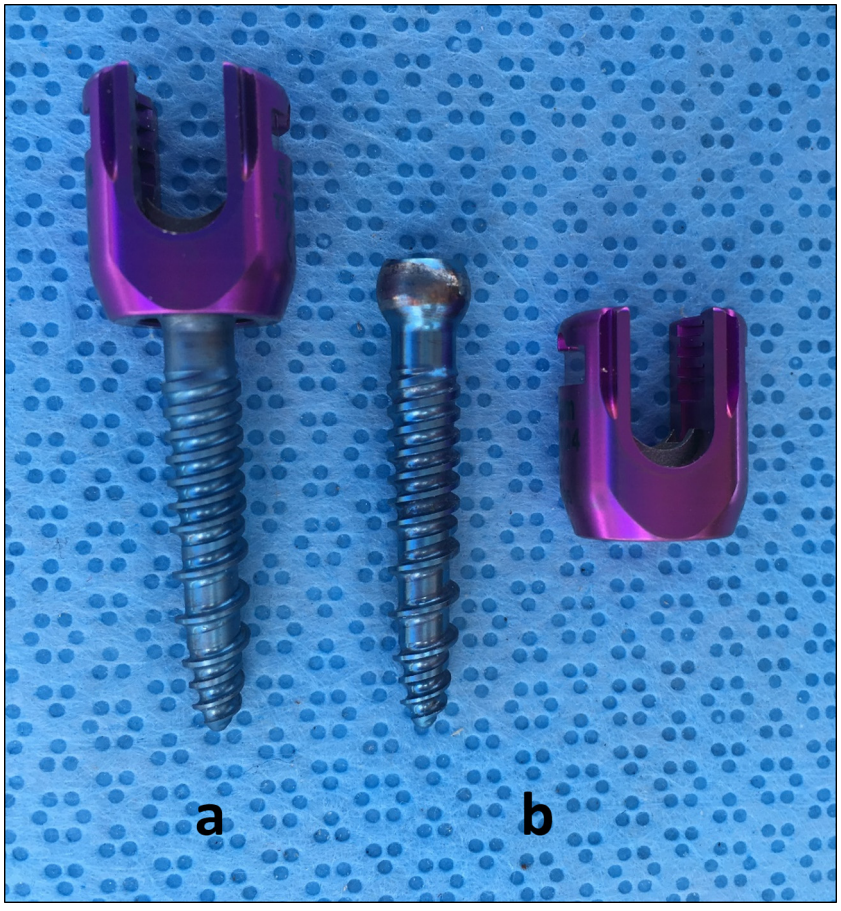

Fig. 1. Pre-assembled head screw (a) and modular head screw (b).

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