Insertional torque and pullout strength of pedicle screws with or without repositioning: a porcine study

Chun Ee Tan,1 Margaret Woon Man Fok,2 Keith Dip Kei Luk,2 Kenneth Man Chee Cheung2
1 Department of Orthopaedics and Traumatology, Penang Hospital, Penang, Malaysia
2 Department of Orthopaedics and Traumatology, The University of Hong Kong, Hong Kong

ABSTRACT

Purpose. To evaluate the insertion torque and pullout strength of pedicle screws with or without repositioning.
Methods. 20 fresh porcine lumbar vertebrae of similar size were used. The entry point was at the site just lateral and distal to the superior facet joint of the vertebra, and to a depth of 35 mm. A 6.2-mm-diameter, 35-mm-long pedicle screw was inserted parallel to the superior end plate on one side as control. On the other side, an identical screw was first inserted 10º caudal to the superior end plate, and then repositioned parallel to the superior end plate. The insertional torque and pullout strength were measured.
Results. Three of the specimens were excluded owing to pedicle fractures during the pullout test. Repositioned pedicle screws were significantly weaker than controls in terms of the maximum insertional torque (3.20±0.28 vs. 2.04±0.28 Nm, 36% difference, p<0.01) and pullout strength (1664±378 vs. 1391±295 N, p<0.01).
Conclusion. Repositioning pedicle screws should be avoided, especially when the pedicle wall is breached. If repositioning is deemed necessary, augmentation with polymethyl methacrylate or a screw with a larger diameter should be considered.

Key words: bone screws; spine; torque

INTRODUCTION

Pedicle screw and plate fixation has been widely used for treating spinal trauma, deformities, and fusion augmentation. It enables better stability and control in the correction of spinal deformities than other forms of fixation.1-3 Insertion of each pedicle screw into an optimal position is technically demanding. The size and orientation of each pedicle is different at each level. A breach of the pedicle wall during pedicle screw insertion is not uncommon,4 and repositioning a fully inserted pedicle screw is necessary, which enlarges the pedicle hole and removes additional cancellous bone. This may decrease the insertional...
torque and pullout strength of the pedicle screw. Understanding the extent of such a decrease in a repositioned pedicle screw helps to decide whether to perform the remedial or salvage procedure. This study assessed the insertional torque and pullout strength of pedicle screws with or without repositioning in a porcine model. Porcine vertebrae are suitable alternatives to human ones if differences are taken into consideration.6

MATERIALS AND METHODS

20 fresh porcine lumbar vertebrae of similar size were cleaned and removed of all soft tissue and stored at -30°C until used for testing at room temperature after thawing. The sequence of insertion of pedicle screws for each vertebra was randomised by sides to avoid individual differences. The entry point of the pedicle screw was at the site just lateral and distal to the superior facet joint of the vertebra,7 and to a depth of 35 mm. A 6.2-mm-diameter, 35-mm-long pedicle screw (USS II, Synthes, USA) was inserted parallel to the superior end plate on one side as control. On the other side, an identical screw was first inserted 10º caudal to the superior end plate, and then repositioned parallel to the superior end plate.

The insertional torque for every 180º turning of the screw was measured using a torque driver (N50DPSK, Nakamura, Tokyo, Japan; Fig. 1). The pullout strength of each pedicle screw was measured using a servo-hydraulic MTS 858 Bionix testing machine (MTS Systems, Minneapolis [MN], USA). The pedicle screws were pulled out along the axis at a displacement rate of 0.1 mm/s. Comparisons were made using the paired t test. A p value of <0.01 was considered statistically significant.

RESULTS

Three of the specimens were excluded owing to pedicle fractures during the pullout test. Repositioned pedicle screws were significantly weaker than controls in terms of the maximum insertional torque (3.20±0.28 vs. 2.04±0.28 Nm, 36% difference, p<0.01) and pullout strength (1664±378 vs. 1391±295 N, p<0.01, Fig. 2).

DISCUSSION

Pedicle screw fixation is the preferred instrumentation for the thoracolumbar spine.2,3 It enables immediate correction of spine fractures and deformities, and immediate stabilisation of spinal fusions.8 For optimal corrective power, the position of the pedicle screw should be parallel to the superior endplate of the vertebra.9 However, it is technically demanding to place each pedicle screw in an optimal position as the size and orientation of each pedicle change along the spine.10 Breaching of the pedicle wall during pedicle screw insertion is not uncommon.4 The pedicle screw may be placed too cephalic (i.e. breaching the disc space) or too caudal (i.e. breaching the lower endplate).

Figure 1 The insertional torque of a pedicle screw is measured using a torque driver with a constant rotational effort for every 180º turning of the screw.

Figure 2 The mean pullout strength for non-repositioned and repositioned pedicle screws.
Computer navigation enables accurate placement of pedicle screws,\textsuperscript{11,12} and polyaxial pedicle screws enable aligning the screws with other components in a construct. Nonetheless, if the pedicle wall is breached, it is necessary to reposition the pedicle screw in a different trajectory. The rate of pedicle screw loosening can increase up to 25%.\textsuperscript{13,14}

The pullout strength of pedicle screws is affected by the purchase of screw threads at the cancellous bone, particularly the corticocancellous interface of the pedicle, which contributes about 80\% of the stiffness and 60\% of the pullout strength.\textsuperscript{14} Tapping of pedicle screws prior to insertion negatively affects the insertional torque, as it removes cancellous bone to an extent of up to 27\%.\textsuperscript{15} Replacing with a pedicle screw of similar diameter results in a 34\% decrease in pullout strength.\textsuperscript{16} Repositioning the pedicle screw trajectory removes additional cancellous bone and enlarges the trajectory and thus affects fixation stability.

Insertional torque of pedicle screws positively correlates with \textit{in vivo} screw pullout strength and thus fixation stability.\textsuperscript{17,18} In our study, the insertional torque and pullout strength of pedicle screws decreased significantly (36\%) after repositioning.

If the pedicle wall is not breached, augmentation with bone cement may improve the pullout strength of pedicle screws. Polymethylmethacrylate is reported to increase the pullout strength 49\% to 162\%.\textsuperscript{19,20} Both polymethylmethacrylate and calcium sulphate are reported to improve pedicle screw pullout strength 199\% and 167\% respectively when compared with the native bone.\textsuperscript{21} Calcium sulphate graft augmentation is reported to achieve 142\% of pullout strength.\textsuperscript{22}

Failed or breached pedicles at the thoracic vertebrae can be salvaged by an anatomic trajectory technique or in-out-in technique, but these can provide only about 60\% of the fixation strength of a standard fixation technique.\textsuperscript{9} Hydroxyapatite-coated pedicle screws improve fixation stability in the long term.\textsuperscript{23} An increase in the pedicle screw diameter increases the insertional torque of the screw.\textsuperscript{16} Thus, using a larger diameter screw for repositioning may improve the biomechanical strength to a certain extent, but salvaging a breached pedicle may not be safe owing to proximity to the spinal cord/nerve root.

The strength of each pedicle screw contributing to the entire pedicle screw–rod construct is unknown. Thus, the extent of the decrease in stability of the entire construct \textit{in vivo} caused by a ‘loose’ pedicle screw may not be clinically significant.

CONCLUSION

Repositioning pedicle screws should be avoided, especially when the pedicle wall is breached. If repositioning is deemed necessary, augmentation with polymethyl methacrylate or a screw with a larger diameter should be considered. At times, the entire construct and fusion segment may need to be extended.\textsuperscript{14,15}

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DISCLOSURE

No conflicts of interest were declared by the authors.