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CLINICAL RESEARCH

# CT Provides Precise Size Assessment of Implanted Titanium Alloy Pedicle Screws

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**Abstract**
*Background* After performing instrumented spinal fusion with pedicle screws, postoperative imaging using CT to assess screw position may be necessary. Stainless steel implants produce significant metal artifact on CT, and the degree of distortion is at least partially dependent on the cross-sectional area of the implanted device. If the same effect occurs with titanium alloy implants, ability to precisely measure proximity of screws to adjacent structures may be adversely affected as screw size increases.
*Questions/purposes* We therefore asked whether (1) CT provides precise measurements of true screw widths; and (2) precision degrades based on the size of the titanium implant imaged.
*Methods* CT scans performed on 20 patients after instrumented spinal fusion for scoliosis were reviewed. The sizes of 151 titanium alloy pedicle screws were measured and compared with known screw size. The amount of metal bloom artifact was determined for each of the four screw sizes. ANOVA with Tukey's post hoc test were performed to evaluate differences in scatter, and Spearman's rho coefficient was used to measure relationship between screw size and scatter.
*Results* All screws measured larger than their known size, but even with larger 7-mm screws the size differential was less than 1 mm. The four different screw sizes produced scatter amounts that were different from each other ($p < 0.001$).The amount of metal bloom artifact produced does increase as the size of the screw increases (rho = 0.962, $p < 0.001$).
*Conclusions* CT of titanium alloy pedicle screws produces minimal artifact, thus making this the preferred imaging modality to assess screw position after surgery. Although the amount of artifact increases with the volume of titanium present, the degree of distortion is minimal and is usually less than 1 mm.

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Each author certifies that his or her institution approved the human protocol for this investigation, and that all investigations were conducted in conformity with ethical principles of research. Informed consent was not required for this retrospective review of radiographic imaging.


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## Introduction

The use of pedicle screws for treatment of spinal deformities has increased in popularity [3, 10, 15, 20, 27, 34]. Pedicle screws are purported to provide several advantages over other available implants: higher pullout strength, ability to save distal fusion levels, better apical vertebral derotation, and improved curve correction, to name a few. However, use of pedicle screws involves some risk, especially if the pedicle wall is violated or the screw tip extends anywhere outside the vertebral body. Numerous authors reported misplaced screws with resultant nerve root compression, impingement on vascular structures, or spinal cord injury [4, 6, 13, 23]. In situations where postoperative imaging is required to assess implant position, several options exist, including plain radiography, CT, and MRI. Plain radiographs may show gross screw malposition, but advanced imaging is required to truly verify screw position in three dimensions [1]. Numerous authors have reported significant metal artifact when imaging stainless steel implants with CT or MRI making image interpretation difficult [2, 14, 17, 24, 26]. The degree of artifact produced is dependent on the cross-sectional area of the implant imaged. Some authors have recommended using smaller implants, spaced farther apart, to improve postoperative imaging [24, 31], but this may compromise fixation strength and ability to effect curve correction. Many surgeons have switched to using titanium, or titanium alloy, implants for superior postoperative imaging capability [14, 25, 28, 31]. However, if the same volumetric effects occur with titanium alloy implants, larger implants might make assessment of screw proximity to neurovascular structures less precise. To our knowledge, no one has quantified the effect cross-sectional area has with respect to postoperative imaging of titanium alloy pedicle screws.

We therefore asked whether (1) CT provides precise measurements of true screw widths for titanium alloy screws; and (2) precision degrades based on size of the titanium alloy implant imaged owing to increasing bloom artifact.

## Materials and Methods

From August 1999 through July 2002, all patients with adolescent idiopathic scoliosis who underwent deformity correction using thoracic and lumbar pedicle screws were reviewed. In our early experience using thoracic pedicle screws for spinal deformity correction, all patients underwent postoperative CT scans to assess implant position. Based on a successful learning curve for thoracic screw placement, we no longer order routine postoperative CT imaging, so the decision was made to use this earlier surgical cohort to find enough screws to form the basis for this study. Twenty patients were identified in this period, and this yielded 151 titanium alloy pedicle screws to study. Pedicle screws are classified by the FDA as Class III devices for use in the thoracic, lumbar, and sacral spine. The postoperative CT scans for these patients were retrospectively reviewed.

All patients underwent instrumented fusion using titanium alloy implants (DePuy Acromed, Raynham, MA, USA). The screw size implanted at each spinal level was recorded in the operative notes. All CT scans were performed using a GE Lightspeed 4-Slice CT scanner (GE Healthcare, Waukesha, WI, USA). No metal suppression protocols or software was used during scanning. The CT scans were reviewed by both authors, both fellowship-trained pediatric orthopaedic surgeons, with each of us measuring 10 studies. We were blinded to the size of the screws being measured. The screw widths were measured using a standard image manipulation software package (GE Centricity™ Version 6, GE Healthcare).

Because an accepted technique to measure screw width on CT scans could not be found in the literature, we standardized screw width measurement by drawing parallel lines along the outer edge of the threads in the axial plane as viewed in bone windows, followed by measuring the perpendicular distance between these lines (Fig. 1). Each screw was measured on every image slice in which the screw appeared. The final screw width recorded was taken

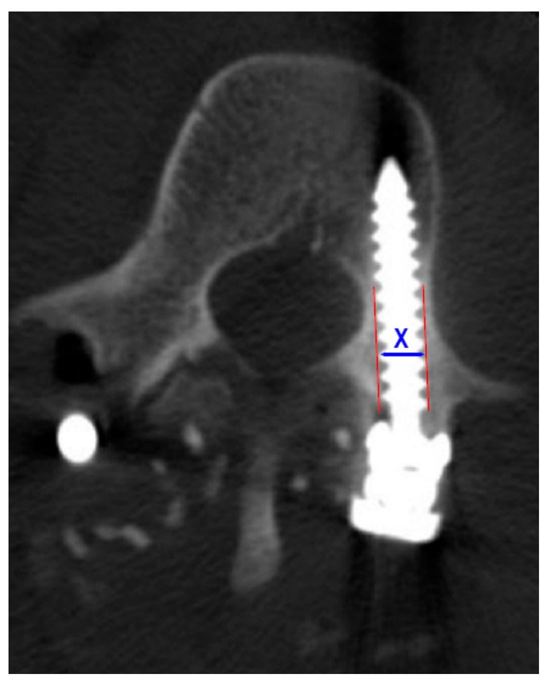


**Fig. 1** The technique we used to measure maximal pedicle width on CT images is shown. X equals the width recorded.

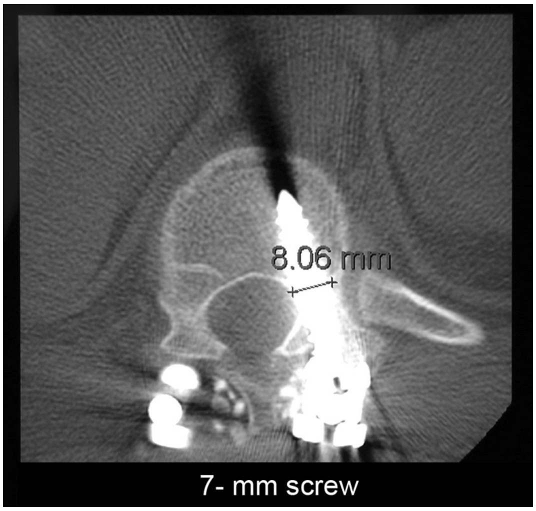


**Fig. 2** The maximum width measured on a CT scan for a 7-mm screw is shown.

from the axial image with the widest measured screw width (Fig. 2). Measurements were not repeated, but multiple measurements were made of each screw on serial axial images to help minimize error. Screw width measurements were recorded at each instrumented level. After all the data were recorded, the operative records were reviewed to determine the true size of each screw, and comparison was made to the measurements made on the CT scan. A percent error was calculated for each screw size. The manufacturer was contacted for information regarding the manufacturing tolerances of the screws; in other words, how accurate was the size of the screw claimed for each screw? Screws sized 5 mm through 7 mm were manufactured to be 0.1 mm smaller than the stated size with a range of ± 0.1 mm. The 4.35-mm screw was manufactured at 4.43 mm with a range of ± 0.075 mm. All screws were manufactured to the level of six sigma tolerance, the industry standard.

The amount of bloom artifact for each screw size was determined by subtracting measured values from actual screw size. One-way ANOVA was performed to evaluate differences in scatter for the different sized screws. Tukey's followup tests were performed to compare the individual size groups. Spearman rho coefficient was calculated to measure the relationship between screw size and the degree of scatter.

## Results

The screw sizes measured on the CT scans were consistently larger than the true screw sizes (Table 1). The percent errors were 8%, 12.4%, 13.2%, and 11.7% for 4.35-mm, 5-mm, 6-mm, and 7-mm screws, respectively.

**Table 1.** Screw size

| Screw size (mm) | Number of screws analyzed | Mean size measured on CT scan (mm) | 95% CI |
|---|---|---|---|
| 4.35 | 45 | 4.7 | 4.30–5.11 |
| 5.0 | 35 | 5.62 | 5.14–6.10 |
| 6.0 | 47 | 6.79 | 6.24–7.34 |
| 7.0 | 24 | 7.82 | 7.51–8.12 |

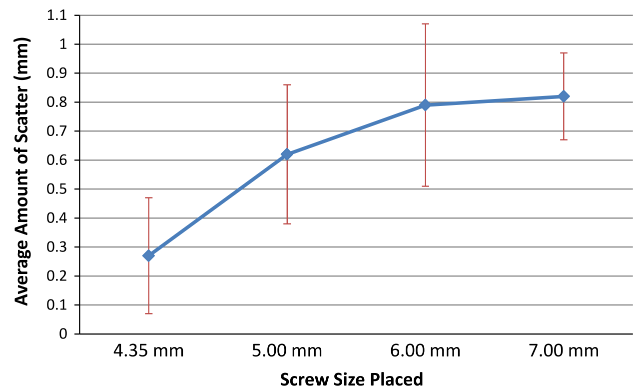


**Fig. 3** The average measured scatter for each screw size measured is shown.

The greatest amount of scatter occurred with the largest screws, with the amount of scatter gradually increasing from smaller to larger screws (Fig. 3). A one-way ANOVA of the four screw groups showed different scatter for the different sizes ($p < 0.001$). Tukey's followup tests showed that the scatter varied among the groups ($p < 0.001$). Not only was the scatter in the first group less than the last group, but all the groups were different from each other. A Spearman's rho coefficient of 0.962 showed a trend that increasing screw size led to greater scatter ($p < 0.001$). Despite the distortion, however, the measured screw size was within 1 mm of the actual screw size in all cases.

## Discussion

The use of thoracic pedicle screws in the treatment of pediatric spinal deformity has increased in popularity [3, 10, 15, 20, 27, 34]. Several studies have been devoted to developing safe techniques for screw placement [3, 5, 8, 9], whereas others focus on anatomic structures at risk during screw placement [5, 7, 12, 16, 19–22, 29, 30, 32, 33]. Although rare, neurologic injury as a result of malpositioned pedicle screws has been reported [4, 6, 18, 23]. When postoperative neurologic changes occur, it is vital that the surgeon have a reliable method to image the spine to look for iatrogenic injury. CT has been used for this purpose but has been shown to produce significant metal artifact when imaging stainless steel implants, making image interpretation difficult [2, 14, 17, 24, 26]. Since volume, or size, of implant adversely affects image quality, surgeons can choose to downsize spinal implants trading fixation strength for improved postoperative imaging capability [26, 31]. Another option is to use titanium implants, which have been shown to produce less bloom artifact [14, 26, 31]. However, to our knowledge, no study has addressed whether increasing size of titanium implants exhibit similar degradation of postoperative imaging. We aimed to answer this question by asking whether: (1) CT provides precise measurements of true screw widths of titanium screws; and (2) precision degrades as the size of the titanium implant increases.

Several limitations of this study should be noted, not least of which is the age of the data set. We now only rarely order postoperative CT scans, and did not have enough recently imaged screws to put together a large data set. We opted to use the data from our early experience with thoracic screws, as we had ample screws in this data set. The older data set also meant use of an older CT scanner. Although newer CT scanners have metal reduction protocols, not all community hospitals have upgraded systems, so knowing that older systems provide precise data is beneficial to many surgeons not in tertiary care facilities. Finally, newer implants combining titanium alloy screws with cobalt-chromium tulips or rods are now in use. While these cobalt-chromium devices are stronger, they are also more expensive, and these newer implants are not universally used. However, Trammell et al. [28] showed, in a subjective way, that image quality is not degraded when comparing titanium alloy implants alone with titanium alloy screws in the presence of cobalt-chromium tulips and rods.

Another limitation of our study concerns our technique of measurement. First, screw widths were measured only on the axial plane. If a screw traverses the axial plane obliquely, such as from lateral to medial as many screws did, the resulting axial slice would be more oval and, therefore, larger. We believe we corrected for this by measuring perpendicular to the long axis of the screw and taking the axial slice with the largest measured diameter. We chose not to measure the screws on reconstructed images in different planes because we were unsure if we could counteract the error created by an out-of-plane screw. Second, we are unable to report on interobserver error of our measurement system because we shared the measurement burden between us. We also cannot report intraobserver error as we did not return to the images for repeated measurements; however, we did measure the same screw on every available axial slice and consistently chose the largest measured diameter, thereby diminishing measurement errors. Despite these limitations, we believe our measurement method to be valid and reflective of the amount of artifact produced by this imaging modality.

Our study showed that CT imaging of titanium alloy screws from 4.35 mm to 7 mm is precise. Percent error in measuring screw size varies from 8% to 13%, and the screws never measured more than 1 mm larger than actual size. Information regarding screw width measurement imaging error may be helpful for surgeons. For example, Gertzbein and Robbins [11] suggested that up to 4 mm of spinal canal encroachment by an implant should be considered in the safe zone of the epidural and subarachnoid space. If a 7-mm screw encroaches the canal by 3 mm, based on our study, the true encroachment is less than 3 mm with no chance of there being more than 3-mm encroachment. As such, there may be less impetus for exploration and implant revision. Any screw malposition in the setting of a neurologic injury is concerning, and surgeons have to use their best clinical judgment when deciding for or against return to surgery for implant revision.

Our study also showed that the amount of artifact produced around titanium alloy pedicle screws is dependent on the size, or volume, of the screw imaged. Smaller-diameter screws produce less metal bloom artifact than do larger-diameter screws. However, even for the 7-mm screw, less than 1-mm size differential was produced by artifact, which equates to less than 0.5 mm on either side of the screw. Because the distortion of screw size is so small, the surgeon can have faith that the CT scan is yielding correct information regarding screw position relative to adjacent structures. Trading implant fixation strength for improved image quality by downsizing pedicle screws is not necessary, as image quality is still excellent even with larger titanium alloy screws.

We found that CT imaging of titanium alloy pedicle screws yielded precise information regarding screw size. The amount of bloom artifact produced by titanium alloy implants is subject to the size of screw imaged; however, even for the 7-mm screws, the amount of distortion is minimal and usually 1 mm or less. Because screw size can be measured precisely, and because bloom artifact is small, CT scanning of titanium alloy implants may be considered the preferred imaging modality when trying to verify screw position and proximity to vital structures.

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