Insertion torque and pullout force of rescue screws for anterior cervical plate fixation in a fatigued initial pilot hole

TOBIAS PITZEN, M.D., PH.D., FREDERICK FRANTA, M.D., DRAGOS BARBIER, M.D., AND WOLF-INGO STEUDEL, M.D.

Neurosurgical Department, University of Saarland, Homburg, Germany

Object. The purpose of this study was to investigate whether thicker-core-diameter screws increase fixation strength in the cervical spine.

Methods. Bone mineral density (BMD) was determined for each vertebral body (VB) obtained in six human C4–7 segments. Based on their BMD, the specimens were assigned to one of two groups in which torque and pullout force were tested. Two initial pilot holes were drilled into the VBs and tests were first performed using a standard screw. The test was repeated using a thicker rescue screw inserted into the same initial pilot hole. The mean value of peak torque and pullout force resulting from the single left/right measurements was used for statistical analysis. A t-test was performed to determine the effect of screw design on peak torque and pullout force. Moment correlation coefficients were calculated to determine the effect of BMD on peak torque and pullout force.

Mean insertional peak torque for the standard screw was 82.1 N/cm and that for the rescue screw was 47.6 N/cm (p < 0.001). There was a strong correlation between insertional peak torque and BMD for both standard screws (r = 0.71, p = 0.02) and rescue screws (r = 0.59, p = 0.07). The mean pullout force for standard screws was 464.7 N, whereas it was 164.5 N for rescue screws (p < 0.001). There was a strong correlation between pullout force and BMD for both standard (r = 0.75, p = 0.0081) and rescue screws (r = 0.7, p = 0.025).

Conclusions. Uncemented rescue screws that have been inserted into a fatigued hole in the cervical VB do not strengthen the screw–bone interface compared with the strength initially conferred by a standard screw.

Key Words • cervical spine • screw • osteoporosis • biomechanics

Fixation of implants within osteoporotic bone remains challenging despite many attempts. Bone cement has been used for tight fixation of total-hip prosthesis and remains in common use. It has also been shown to be useful to increase holding strength of lumbar pedicle screws. Some authors have proposed a thicker screw design to strengthen the bone–screw interface, whether involving a thicker core or expanding screw design.

The simplest tactic has been to use thicker-core-diameter screws. Unfortunately, only one study has been performed to analyze the effectiveness of thicker screws for anterior cervical plate fixation.

Therefore, the objective of the present study was to investigate whether thicker-core-diameter screws increase fixation strength in the cervical spine.

Materials and Methods

Specimen Preparation

Six human cervical spine segments (C-4 to C-7) were explanted during routine autopsy investigations in fresh human cadavers (mean age at death 67.2 ± 6.7 years [range 56–75 years]). They were stored in double plastic bags at −20°C. After careful removal of the attached muscles, BMD was measured for each VB by obtaining a quantitative computerized tomography scan through its middle third section (XCT 960 A; Stratec, Birkenfeld, Germany). Each vertebra was dissected from the segment, yielding 24 single vertebrae. Steel wires were wrapped around the lamina of each vertebra. The spinous process and the lamina with the attached wires were mounted into polymethylmethacrylate (Technovit 3040; Heräus Kulzer, Wehrheim, Germany) with the anterior surface of each VB placed horizontally and turned upward.

Two 14-mm-long initial pilot holes were drilled into the midsection of each VB parallel to the sagittal plane with a distance of at least 1 cm from each other by using a 2.7-mm drill bit (Aesculap AG and CoKG, Tuttingen, Germany). The posterior cortical shell was not perforated. Based on the BMD, the specimens were assigned to one of two groups in which torque and pullout force were tested.

Screw Characteristics

A self-tapping 16-mm-long screw (outer diameter 4 mm, inner conical diameter 2.2 mm at the tip, increasing to 2.7 mm at its head) was first inserted into each initial pilot hole to analyze insertional peak torque and pullout force. This screw will hereafter be called the standard screw. This screw was removed after testing. A non–self-tapping screw 16 mm long (outer diameter 4.5 mm, inner diameter 3.7 mm) was inserted into the damaged hole, and the test was repeated. This screw is termed the rescue screw.

Peak Insertional Torque and Pullout Force

Insertional peak torque was measured using an electronic custom-modified 10-N torque wrench (Dr. Staiger, Mohilo, and Co., J Neurosurg: Spine / Volume 1 / September, 2004

Abbreviations used in this paper: BMD = bone mineral density; SD = standard deviation; VB = vertebral body.
Cervical spine standard and rescue screws

GmbH, Lorch, Germany) during insertion. The accuracy of the wrench exceeds 0.5%. Peak torque was defined as the highest value of torque measured during insertion. The mean value of peak torque resulting from the two single left/right measurements was used for statistical analysis.

For investigation of pullout forces, the heads of the screws were fixed in a metal cylinder to avoid any kind of coupled motion during the pullout test and to allow distractive force along the screw’s axis. The metal cylinder was made with a central perforation through which the screw was inserted into the VB. The area at the bottom of the cylinder was machined precisely to match the shape of the screw head. The cylinder below the area to take the screw was 8 mm in length and 4 mm in diameter, thus allowing alignment of the axis of the box with the axis of the screw. The cylinder was then aligned to the axis of the machine. A material testing machine (Zwick, Ulm, Germany) was used for that part of the study. A preforce of 5 N was applied, and a pullout test was performed under displacement controlled using a constant speed of 0.25 mm/second. Pullout force was defined as the highest value measured during testing. The mean value of pullout force resulting from the two single left/right measurements was used for statistical analysis.

Statistical Analysis

Data were collected on a computer running TestXpert software (Zwick). The mean values ± SD were calculated for peak torque and pullout force. A paired t-test was used to determine the effect of screw design on these two variables. Pearson moment correlation coefficients were calculated to determine the effect of BMD on peak torque and pullout force. A 95% confidence level was used for all tests. Values are presented as the means ± SDs.

Results

Peak Insertional Torque

The mean BMD for insertional peak torque for both screws was 206.6 ± 35.2 mg/cm². Peak insertional torque for the standard screw was 82.1 N/cm and that for the rescue screw was 47.6 N/cm. This difference was statistically significant (p < 0.001; Fig. 1 upper). There was a strong correlation between insertional peak torque and BMD for both the standard (r = 0.71, p = 0.02) and rescue screws (r = 0.59, p = 0.07) (Fig. 1 lower).

Pullout Forces

The mean BMD for pullout force for both screws was 201.5 ± 29.4 mg/cm². Pullout force for the standard screws was 464.7 N and that for the rescue screws was 164.5 N (Fig. 2 upper). This difference was statistically significant (p < 0.001). There was a strong correlation between pullout force and BMD for both the standard (r = 0.75, p = 0.0081) and rescue screws (r = 0.7, p = 0.025) (Fig. 2 lower).

Discussion

We found that rescue screws inserted into damaged initial pilot holes of the cervical VBs do not strengthen the screw–bone interface compared with the strength initially conferred using a standard screw.

Tight fixation of implants is required to obtain sufficient initial stability of a spinal segment. If screw-based implants are used for spinal stabilization, screw fixation should be as firm as possible for optimal initial stability. The strength of the screw fixation is mainly determined by the screw’s insertional torque and pullout force. Of these, insertional torque may be estimated or measured by the surgeon to judge the screw fixation strength. In case of insufficient screw torque, both spreading-type screws and thicker-core-diameter screws have been recommended for fixation of cervical plates. The latter are more commonly used and are often named rescue screws; however, only one biomechanical study has been conducted to assess fixation strength when thicker screws are used with plates within the cervical VB. Zink has compared insertional torque for standard 3.5- and 4.5-mm cancellous screws placed within the VBs. The screws were inserted into the VBs until they failed. A significantly higher torque value was found for the 4.5-mm rescue screws. This finding contradicts the results of our study. We found that rescue screws inserted into a fatigued initial pilot hole did not strengthen the screw–bone interface compared with that initially achieved using a standard screw. Yerby, et al., have compared pullout forces associated with uncemented 6-mm pedicle screws and those associated with uncemented 7-mm pedicle screws placed within the same hole. They found that 7-mm pedicle screws yielded only 73% of the force of the smaller screws. This finding is similar to ours.

A strong correlation was found for both screw types when determining insertional torque and pullout compared with BMD, highlighting the major importance of BMD for fixation strength of spinal implants, which has been described previously.
Although rescue screws applied clinically do not increase insertional peak torque and pullout force compared with the initial strength conferred by the standard screw, this is not to imply that rescue screws do not at all increase these parameters. It must be noted that a free-spinning standard screw has a very low peak torque. Compared with this, the implant–bone interface may be improved by placement of a rescue screw; however, its strength will be significantly diminished. In osteoporotic bone, however, an even better fixation should be achieved compared with that in the standard condition.

There are some limitations of the present study. First, pure uniaxial distraction forces along the axis of the inserted screws were applied to remove the screws. Certainly this loading scenario is somewhat unphysiological, thus not reflecting the complex clinical situation; however, the loading conditions used in this test are accepted in spinal biomechanics and comparable with the aforementioned studies. This makes comparison of our results with other in vitro experiments, at least partially, feasible. Cyclic loading has not been performed. Therefore, the results do not represent the situation following repetitive motion in activities of daily living. Second, we used each VB as its own control to compare fixation of the standard and rescue screws within the same specimen. Especially for pullout testing, this may result in traumatic changes of the bone’s microarchitecture, which could influence the results. Therefore, we ensured a distance of 1 cm between both screws, and no major damage was observed after pullout testing. Finally, it is difficult to determine if the results of qualitative CT scanning, which indicated lower BMD quality, justify a diagnosis of osteoporosis; the region of interest in which density was measured must not necessarily be representative of the complete VB. Therefore, our BMD measurements do not necessarily indicate that these specimens were osteoporotic, but they may suggest so.

Translation of biomechanical in vitro results to clinical application is difficult. In vitro testing, however, is performed to provide recommendations for clinical application. Based on the results of the present study and other in vitro investigations, the role of thicker-core-diameter rescue screws has been, at the very least, debatable and, likely, has been overemphasized.

Conclusions

Uncemented rescue screws that have been inserted into a fatigued initial pilot hole of the cervical VBs do not strengthen the screw–bone interface any more than that achieved initially using standard screws.

Disclaimer

The authors do not have any financial interest in any of the implants used in the current study.

References


T. Pitzen, et al.
Cervical spine standard and rescue screws


Manuscript received November 24, 2003. Accepted in final form May 25, 2004. Material support (implants and tools) was provided by Aesculap AG and CoKG, Tuttlingen Germany. 

Address reprint requests to: Tobias Pitzen, M.D., Neurochirurgische Klinik, Universitätsklinik des Saarlandes, 66421 Homburg, Germany. email: pitzen@t-online.de.