

Pedicular screw fixation in osteoporotic vertebrae: intraoperative evaluation of local bone strength and bone augmentation via perforated pedicular screws.

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Posterior spinal fixation systems undergo internal constraints resulting in high load bearing requirement for the pedicular screw/bone interface. Different studies have proven that the screw performance is dependent on the bone quality. We have developed perforated screws for cement augmentation in osteoporotic vertebrae and analysed stiffness and screw migration.

To decide which vertebrae will need augmentation an intraoperative measurement of local bone density is required. Previous work of our group reported on laboratory evaluation of mechanical torque measurement as a method for the intraoperative quantification of bone strength and on the development of a related instrumentation for proximal femur fractures with DensiProbe™ Hip [1].

With the laboratory study presented here we intend to verify two different methods to evaluate the bone strength of trabecular bone in spinal instrumentation with pedicle screw techniques. In a specific protocol the global BMD of the vertebral body of lumbar vertebrae was compared with the mechanical strength of this anatomical region. The objective of this study was to evaluate two different measurement principles and to correlate the mechanical competence with BMD of the region around the pedicle screw tip.

Material

Mechanical measurement probes: Two principles of measurement techniques for intraoperative use to measure torque and indentation to breakaway of trabecular bone: Torque Measurement Tool (TMT) with a common data acquisition unit (HIOS HDM-100, Intechnik AG). Indentation Measurement Tool (IMT) with load cell (Burster Miniature Load Cell) and USB-Sensor Interface (type 9205) with the configuration software (MTS-Messtechnik GmbH). Hydraulic actuator MTS Mini Bionix 858. XtremeCT, Scanco Medical. 10 fresh frozen human lumbar vertebrae, level 4; BMD 56.1 to 117.0 mgHA/cm³. 20 USS-II pedicle screws, D5.2mm, Synthes Inc. USS-II Instrumentation, Synthes Inc.

Methods

The vertebrae were mounted in respect to prone position, fixed in a vice. The handling was adapted to the standard Universal Spinal System (USS-II, Synthes Inc.) operation technique for segmental correction and stabilization. The instrumentation procedure was controlled with fluoroscopy. After preparing the screw canal a spine surgeon inserted the TMT and measured the breakaway torque. For

the measurement with the IMT, a rod inside of the cannulated tip will be pushed into the trabecular bone to evaluate the resistance. After evaluation pedicle screws were inserted. The specimens were loaded in caudo-cranial direction according to studies of Reinhold [2] and Ferguson [3]. Therefore the pedicle screw heads were embedded in PMMA. Dynamic loading was applied to the cranial endplate through a metal ball on the end of the hydraulic actuator. A fluoroscope was used to determine the migration of the screws relative to the bone. Dynamic loading with a lower level of 20N was continuously increased from 100 to 800N at 0.035N/cycle until failure of the construct.

Results

High correlations were found between indentation load and breakaway torque ($r = 0.931$, $P < 0.001$). Also a high correlation could be shown between indentation load and BMD ($r = 0.929$, $P < 0.001$). Although the range of the torque measurement was less than 0.3Nm, a high correlation between breakaway torque and BMD could be established ($r = 0.924$, $P < 0.001$). Six out of ten specimens could be used for evaluation of the failure load. The evaluation of the indentation and failure load of the 6 specimens showed a significant correlation between these two parameters ($r = 0.968$, $P < 0.001$). Also a correlation between breakaway torque and failure load could be found ($r = 0.855$, $P = 0.030$).

A significance for the correlation between BMD and load to failure could also be determined ($r = 0.827$, $P = 0.042$).

Conclusions

For the evaluation of a predictive value for the cut-out resistance of pedicle screw, both tested tools seem to be appropriate. The holding strength of the pedicle screw was significantly influenced by both mechanical parameters, the indentation load and breakaway torque. The relation between BMD and load to failure could also be reflected. It is expected that the small number of specimens due to adaptations of the test protocol has an influence on the result. For a clear conclusion, which principle has to be considered as predictive value for the cut-out risk of pedicle screws, the final setup should be optimized.

References

1. Suhm et al. Arch Orthop Trauma Surg 2007
2. Reinhold et al. Spine 2006
3. Ferguson et al. Eur Spine J 2002