Advancements in Surgical Techniques in Osteoporotic Patients

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Abstract:

Osteoporosis (OP) is a major global health concern, with aging being one of the most important risk factors. Osteoarthritis (OA) is also an age-related disorder. Patients with OP and/or OA may be treated surgically for fractures or when their quality of life is impaired. Poor bone quality due to OP can seriously complicate the stability of a bone fixation construct and/or surgical fracture treatment.

Keywords: osteoporosis; bone-related surgeries.

Introduction:

To increase the pull-out strength of a pedicle screw, it has been suggested to increase the screw's diameter and length and use an insertion technique that involves under-tapping a pilot hole and using a pilot hole smaller than the screw's core diameter. However, because of the thin cortex of the pedicle, it was discovered that larger screws had no influence on the fixing strength in osteoporotic bone. It has been demonstrated that additional methods, such as the use of longer constructs, additional anterior fixing, transverse connectors, triangulation techniques, laminar hooks, or sub-laminar wires, increase the rigidity of the build (2).

It is frequently advised to increase the number of fixation sites in an osteoporotic spine fixation in order to reduce stress and enhance stability. Either the standard number of fixation levels can be extended, or other structures like sub-laminar wires or laminar hooks can be used in addition to the standard pedicle screw fixation. According to Butler et al.'s investigation, osteoporosis has no negative effects on laminar hook fixation (3). In osteoporotic thoracic spines, sublaminar hooks exhibit better biomechanical stability than wires or pedicle screws (4). A variety of fastening methods can aid in distributing the osteoporotic bone's stresses. Pedicle screws and hooks, commonly known as pediculolaminar fixation, have been shown to boost pullout strength by up to 100% (5). Additionally, they can improve torsional stability in osteoporotic bone and stiffen the construct (3).

Additionally, a circumferential fusion relieves the posterior construct of some of the stress and permits load sharing. Anterior column support can be achieved by using posterior and transforaminal lumbar interbody fusion methods. But for fusion to be successful, end plate preparation must be done with great care, and the right size interbody spacer must be used. For a successful fusion, Okuda et al. have suggested using a large amount of bone graft and preserving the osseous end plate (6). In order to allow the implant to sit on a cancellous basis and promote fusion, a few writers also suggest removing the osseous end plate. However, given the weak cancellous base in osteoporosis, this must be addressed seriously. Additionally, while choosing additional anterior fusion, one must weigh the increased surgical risk, blood loss, and operating time (7).

Cement augmentation

In main and revision procedures, PMMA (polymethyl methacrylate) augmentation increases the pull-out strength of screws by 119% and 162%, respectively (8). PMMA's exothermic qualities, the possibility of neural tissue damage in the event of extravasation, and the challenge of performing revision surgery are its drawbacks. Therefore, it was recommended to utilize biodegradable cements. Using calcium phosphate and calcium apatite cements, respectively, produced good results (9).

At the operating level, hydroxyapatite (HA) augmentation minimized subsidence, decreased the chance of screw build angular displacement, and improved the screw-bone interaction. This differs slightly from HA-coated screws in that it allows for the augmentation of only the screw's distal tip, which facilitates extraction, while HA-coated screws increase the torque generated during extraction by augmenting the entire screw length (10).

Although using biodegradable cements makes screw removal less laborious than using PMMA, they require more time to cure—up to 24 hours—and hence won't provide better fixation during surgery.

Although they have not yet been proven, indirect techniques such as bone cement augmentation into the disc gap for percutaneous pedicle screw fixation for lumbar fusion procedures have also been suggested as secure and cost-effective substitutes (11).

Prophylactic vertebroplasty augmentation of segments above and below the instrumented fusion levels has been investigated as a means of preventing neighboring segment fractures, in addition to cement augmentation of screws (12). Additionally, it has been shown to lower the risk of kyphosis at the proximal connection (13). Additionally, preventive augmentation procedures have been linked to more severe and subsequent spinal fractures (14).

Cortical bone trajectory technique

In order to lower the frequency of issues related to traditional pedicle screws, the cortical bone trajectory (CBT) technique was created and initially reported by Santoni et al. in 2009 (15).

In contrast to traditional screws, which engage cancellous bone and are directed convergently along the pedicle's anatomical axis, CBT screws maximize thread contact with the pedicle's and vertebrae's cortical bone. These bones begin at the junction of the superior articular process and pars and follow a medial-lateral path in the transverse plane and a sagittal caudocephalad path (16).

Biomechanical investigations have validated the screw-rod construction's greater pullout strength, larger insertional torque, and adequate stability when compared to traditional fixation (17). Additionally, there is less injury to the multifidus muscle, similar clinical results, and fewer instrumentation-related problems (18).

Figure 1: AP (Antero-posterior) and lateral X-ray images of a patient showing the Cortical Bone Trajectory technique for pedicle screw fixation **(19).**

Superior cortical screw technique

Since the pedicle provides roughly 60% of the pull out strength of pedicles screw and the upper third of the pedicle has the densest microstructure, a novel trajectory was attempted with entry point 3 mm above the Magerl’s point and was found to have higher pull out strength **(20)**.

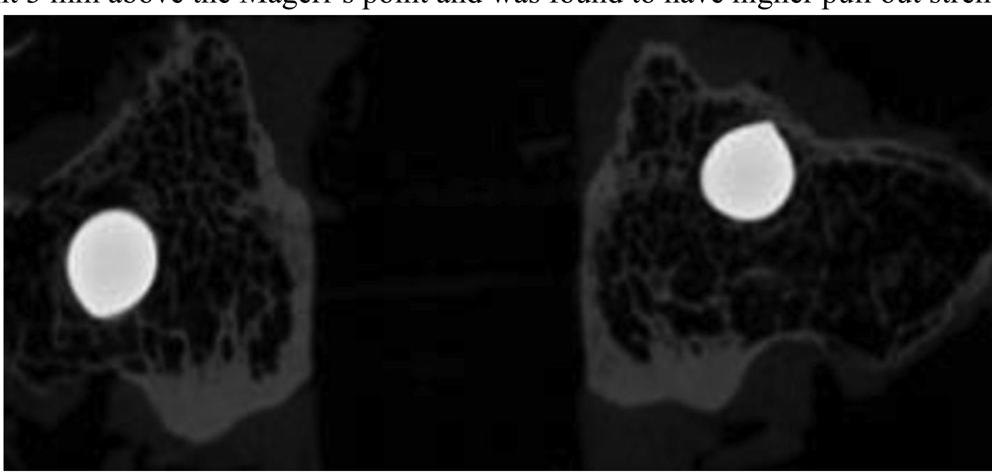

Figure 2: CT image of the pedicles showing the position of a traditional pedicle screw (left) and a superior cortical screw (right) **(20).**

Double screw technique

Biomechanical feasibility studies have shown that the elliptical cross-section of the pedicle would allow the insertion of two smaller diameter pedicle screws resulting in a bony purchase superior to the standard single-screw technique **(21).**

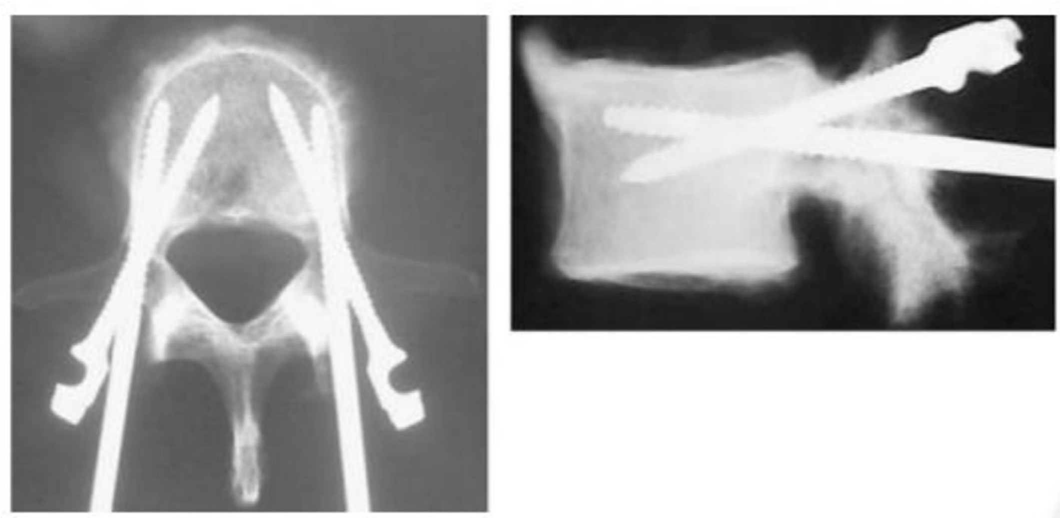

Figure 3: AP and lateral X-ray images of a patient operated by double screw technique of pedicle screw fixation **(21).**

Cross trajectory technique

Matsukawa et al. proposed a novel double-screw technique that combines traditional trajectory (TT) and CBT. This technique involves inserting two screws into an elliptical shape of a single pedicle using different transpedicular trajectories. It was found to have superior fixation strength in each plane of motion compared to the TT and CBT techniques. The more expensive equipment and the technically challenging process, which carries a risk of pedicle fracture and neurological damage, are the drawbacks, nevertheless **(22)**.

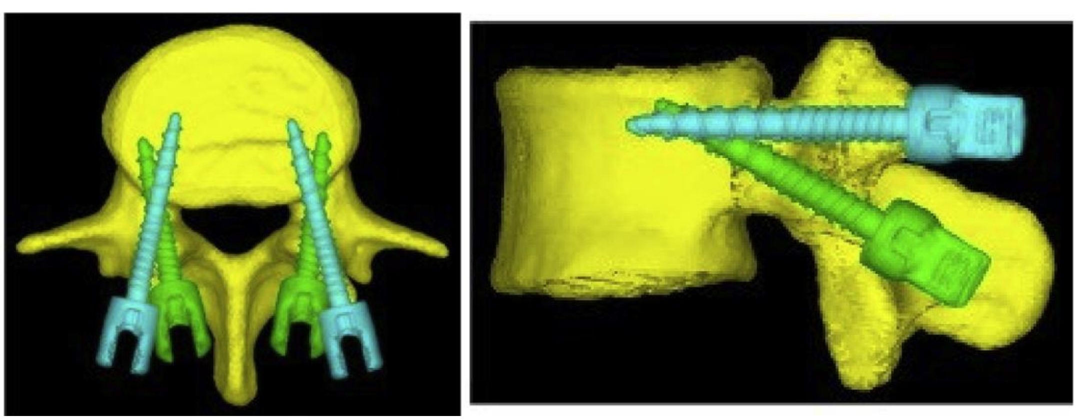

Figure 4: An illustration showing the cross trajectory technique of screw insertion **(22).**

Bicortical screw technique

By expanding the number of cortices engaged, bicortical screw fixation has been proposed as a way to boost the fixation strength. Battula et al. suggested that for sufficient pull-out strength, the screw should be inserted 2 mm past the distant cortex. However, the possibility of harming anterior tissues such as the colon, vena cava, aorta, and sacral sympathetic trunk limits the use of this procedure **(23).**

References:

1. Chatzistergos PE, Sapkas G, Kourkoulis SK. The influence of the insertion technique on the pullout force of pedicle screws: an experimental study. Spine. 2010;35:E332eE337.
2. Hirano T, Hasegawa K, Takahashi HE, et al. Structural characteristics of the pedicle and its role in screw stability. Spine. 1997;22:2504e2510. Phila Pa 1976.
3. Butler Jr TE, Asher MA, Jayaraman G, Nunley PD, Robinson RG. The strength and stiffness of thoracic implant anchors in osteoporotic spines. Spine. 1994;19(17): 1956e1962. Phila Pa 1976
4. Coe JD, Warden KE, Herzig MA, McAfee PC. Influence of bone mineral density on the fixation of thoracolumbar implants: a comparative study of transpedicular screws, laminar hooks, and spinous process wires. Spine. 1990;15(9): 902e907. Phila Pa 1976.
5. Liljenqvist U, Hackenberg L, Link T, Halm H. Pullout strength of pedicle screws versus pedicle and laminar hooks in the thoracic spine. Acta Orthop Belg. 2001;67(2):157e163.
6. Okuda S, Oda T, Miyauchi A, Haku T, Yamamoto T, Iwasaki M. Surgical outcomes of posterior lumbar interbody fusion in elderly patients. J Bone Joint Surg Am. 2007;1(2):310e320.
7. Steffen T, Tsantrizos A, Aebi M. Effect of implant design and endplate preparation on the compressive strength of interbody fusion constructs. Phila Pa 1976 Spine. 2000;25(9):1077e1084. https://doi.org/10.1097/00007632-200005010-00007. preparation on the compressive strength of interbody fusion constructs. Spine (Phila Pa 1976) 2000;25(9):1077e1084.
8. Frankel BM, Jones T, Wang C. Segmental polymethylmethacrylateaugmented pedicle screw fixation in patients with bone softening caused by osteoporosis and metastatic tumor involvement: a clinical evaluation. Neurosurgery. 2007;61:531–7 discussion 537-8

9. Wuisman PI, Van Dijk M, Staal H, Van Royen BJ. Augmentation of (pedicle) screws with calcium apatite cement in patients with severe progressive osteoporotic spinal deformities: an innovative technique. Eur Spine J. 2000;9: 528e533.
10. Jang SH, Lee JH, Cho JY, Lee HY, Lee SH. The efficacy of hydroxyapatite for screw augmentation in osteoporotic patients. Neurol Med -Chir. 2013;53(12): 875e881. https://doi.org/10.2176/nmc.oa2012-0346.
11. Park CK, Park CK, Lee DC, Lee DG. A new technique of bone cement augmentation via the disc space for percutaneous pedicle screw fixation. J Neurosurg Spine. 2016 Jan;24(1):16e19. https://doi.org/10.3171/2015.4.SPINE141115. Epub 2015 Sep. 11
12. Aydogan M, Ozturk C, Karatoprak O, Tezer M, Aksu N, Hamzaoglu A. The pedicle screw fixation with vertebroplasty augmentation in the surgical treatment of the severe osteoporotic spines. J Spinal Disord Tech. 2009;22(6):444e447, 57.
13. Raman T, Miller E, Martin CT, Kebaish KM. The effect of prophylactic vertebroplasty on the incidence of proximal junctional kyphosis and proximal junctional failure following posterior spinal fusion in adult spinal deformity: a 5-year follow-up study. Spine J. 2017;17(10):1489e1498. https://doi.org/10.1016/j.spinee.2017.05.017.
14. Fernandez-Baíllo N, S anchez M arquez JM, Sanchez P erez-Grueso FJ, GarcíaFernandez A. Proximal junctional vertebral fracture-subluxation after adult spine deformity surgery. Does vertebral augmentation avoid this complication? A case report. Scoliosis. 2012;7(1):16.
15. Hung CW, Wu MF, Hong RT, Weng MJ, Yu GF, Kao CH. Comparison of multifidus muscle atrophy after posterior lumbar interbody fusion with conventional and cortical bone trajectory. Clin Neurol Neurosurg. 2016;145:41–45. doi:10.1016/j.clineuro.2016.03.005
16. Matsukawa K, Taguchi E, Yato Y, et al. Evaluation of the fixation strength of pedicle screws using cortical bone trajectory: what is the ideal trajectory for optimal fixation? Spine. 2015;40(15):E873–E878. doi:10.1097/BRS.0000000000000983
17. Matsukawa K, Yato Y, Kato T, Imabayashi H, Asazuma T, Nemoto K. In vivo analysis of insertional torque during pedicle screwing using cortical bone trajectory technique. Spine. 2014;39(4):E240–E245. doi:10.1097/BRS.0000000000000116

18. Liu YZ, Hai Y, Zhang XN, et al. [Comparison of cortical bone trajectory screw fixation and pedicle screw fixation in posterior lumbar fusion]. Zhonghua Yi Xue Za Zhi. 2019;99(19):1473–1478. Chinese. doi:10.3760/cma.j.issn.0376-2491.2019.19.008
19. Dabbous B, Brown DV, Tsitlakidis A, Arzoglou V. Clinical outcomes during the learning curve of MIDline Lumbar Fusion (MIDLF®) using the cortical bone trajectory. Acta Neurochir. 2016;158:1413e1420.
20. Yu T, Zhang X, Liu J, Li S, Shan Z, Fan S, Zhao F. Superior cortical screw in osteoporotic lumbar vertebrae: a biomechanics and microstructure-based study. Clin BioMech. 2018 Mar 1;53:14-21.
21. Jiang L, Arlet V, Beckman L, Steffen T. Double pedicle screw instrumentation in the osteoporotic spine: a biomechanical feasibility study. J Spinal Disord Tech. 2007 Aug;20(6):430e435.
22. Matsukawa K, Yato Y, Imabayashi H, Hosogane N, Asazuma T, Nemoto K. Biomechanical evaluation of cross trajectory technique for pedicle screw insertion: combined use of traditional trajectory and cortical bone trajectory. Orthop Surg. 2015 Nov;7(4):317e323. https://doi.org/10.1111/os.12212.
23. Battula S, Schoenfeld AJ, Sahai V, Vrabec GA, Tank J, Njus GO. The effect of pilot hole size on the insertion torque and pullout strength of self-tapping cortical bone screws in osteoporotic bone. J Trauma Acute Care Surg. 2008;64(4):990. https://doi.org/ 10.1097/ TA.0b013e31802bf051.