J Turk Spinal Surg 2024;35(2):79-84
DOI: 10.4274/jtss.galenos.2024.29491

VERTEBROPLASTY COMBINED WITH TRANSPEDICULAR FIXATION FOR THE MANAGEMENT OF NON-TRAUMATIC OSTEOPOROTIC VERTEBRAL FRACTURES ASSOCIATED WITH PEDICLE FRACTURES

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ABSTRACT

Objective: Non-traumatic osteoporotic vertebra fracture (OVF) in association with bilateral pedicle fracture (PD) is a rare condition. In particular, OVFs demonstrating vacuum cleft sign and superior endplate discontinuity extending to the posterior cortex may be associated with non-traumatic PDs. This coexistence results in an unstable fracture pattern, and when solely treated with vertebroplasty (VP), vertebral collapse develops, leading to dead bone formation. We aimed to evaluate the efficacy of VP combined with transpedicular fixation (TPF) for the management of OVFs associated with PD.

Materials and Methods: Patients treated with VP combined with percutaneous TPF with a fenestrated screw at the same level of OVF were included. Prophylactic VP was performed at one level above and below. All patients underwent magnetic resonance imaging (MRI) and computerized tomography (CT) during preoperative evaluation. Preop and postop CT scans used for vertebral height measurements and comparison.

Results: Thirty-two pts (10M, 22F), mean age 74 (47-92) years of OVF and f/up 30 (24-74) months. Quantative-CT analysis including bone mineral density and t-score mean values was 56.79 mg/cm^3 and -4.38±0.538 respectively. VP combined with TPF was performed at 21 pts (Thoracolumbar), 8 pts (Thoracic), and 3 pts (Lumbar spine). Prophylactic VP was performed at 87 levels. The mean vertebral body angle improvement was 20.9% and the mean local kyphosis angle improvement was 17.2%. The mean anterior vertebral height and posterior vertebral height increased by 13.5% and 3.5%, respectively. None of the pts developed further vertebral collapse and none the pedicle screws pulled out at the final f/up.

Conclusion: According to our study, VP combined with TPF provided stable fixation and prevented further vertebral collapse in patients with OVF associated with pedicle fractures. OVF with a vacuum cleft sign or superior endplate discontinuity extending to the posterior cortex must be evaluated for the coexistence of spontaneous pedicle fracture, which causes instability and vertebral collapse. We recommend routine preoperative CT scan evaluation to determine fracture pattern and check pedicle integrity in addition to MRI scans.

Keywords: Vertebroplasty, transpedicular screw fixation, pedicle fracture, osteoporotic vertebral fractures

INTRODUCTION

Vertebral compression fractures (VCFs) are the most prevalent form of osteoporotic fractures. Although the prevalence of osteoporotic vertebral fractures (OVF) varies according to gender and age, several studies reported a rate between 40-50% among the female population over 50 years of age[1,2]. VCFs lead to pain, kyphosis, reduction in daily activities, and psychological disorders with progressive loss of vertebral height; resulting in a considerable decrease in the life quality of patients[3,4]. On the other hand, the mortality rate of OVFs among elderly patients is higher than that of the normal-age population[5].

Besides the osteoporotic causes, VCFs can be observed in malignancies: such as metastasis of the breast, prostate, thyroid, and lung cancers to the bones, the primary tumors of bone, and the lymphoproliferative diseases (i.e. lymphoma/multiple myeloma)[6]. The discrimination between the osteoporotic VCFs and malignant pathological fractures is

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critical and can be detected by magnetic resonance imaging (MRI) and computerized tomography (CT)[7,8]. Albeit abnormal bone marrow signals involving the pedicles and/or other posterior elements have been considered as a robust indicator of malignancy in VCFs. Ishiyama et al.[9] reported that the sensitivity and specificity of pedicle involvement on MRI were 84% and 36% for pathological malign fractures, respectively. Moreover, they detected the presence of pedicle edema in 144 MRIs of 225 patients with osteoporotic compression fractures and the presence of the pedicle fractures on CT of 31% of patients with pedicle edema[9].

Non-traumatic OVF patients rarely co-exist with bilateral pedicle fractures. Cases demonstrating vacuum cleft signs and superior endplate discontinuity extending to the posterior cortex may be associated with non-traumatic pedicle fractures. This co-existence eventually results in an unstable fracture pattern.

In the treatment of OVFs, both conservative and surgical methods are used. Treatments aim to reduce back pain and prevent the prognosis of deformity. Conservative treatment includes bed rest, brace, and analgesics. Currently, surgical treatment is preferred for patients with uncontrolled pain despite conservative treatment.

Traditionally, the common surgical treatment in elderly patients with OVFs is vertebroplasty due to their existing numerous comorbidities. However, in the unstable fracture pattern of OVFs co-existing with pedicle fracture, only vertebroplasty can develop further vertebral collapse which eventually leads to dead bone formation.

In the present study, we established a percutaneous transpedicular fixation (TPF) following vertebroplasty to support the vertebral corpus from the posterior column in unstable OVFs associated with pedicle fracture. We evaluated the clinical and radiographic outcomes of vertebroplasty combined with TPF surgery performed in patients with OVF associated with pedicle fractures.

MATERIALS AND METHODS

Patient Preoperative Evaluation

From 2017 through 2022, an analysis of 32 patients with OVF surgically treated with vertebroplasty combined with TPF of pedicle fracture at the same level as the OVF was performed. 10 males and 22 females, with an average age of 74 (47-92) years were included in this study. Radiological and clinical evaluations were analyzed in the preoperatively and both early-postoperatively and final follow-up. Postoperative complications were analyzed. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). All patients signed the informed consent for this retrospective study. Ethical approval for this study was obtained from the İstanbul Bilim University Clinical Research Ethics Committee (approval number: 44140529/2016-06, date: 21/01/2016).

Radiological evaluations of the patients including CT scan and MRI were performed. Pedicle fracture was analyzed accordingly using both a CT scan and MRI. Every elderly patient with an OVF associated with pedicle fracture was prepared for vertebroplasty combined with percutaneous TPF with a fenestrated screw at the same level as the OVF. Measurement of vertebral heights and their comparison was performed using preoperative and postoperative CT scans. Also, the bone quality of the patients was analyzed using quantitative computed tomography.

Surgical Technique

All patients were monitored intraoperatively using somatosensory evoked potential (SSEP) and motor evoked potentials (MEP). Following intubation baseline SSEP and MEP values were recorded supine before positioning the patients. To protect the surgical morbidity of pressure sore and peripheral nerve injury, all the patients were well-padded on their bony prominences before positioning. Positioning was done using a Jackson radiolucent, frame with the abdomen freely acquired without any compression and the hips flexed appropriately. SSEP and MEP values were checked immediately after the prone positioning and compared with the initial values of the supine position. Always, the SSEP and MEP values were maintained at the beginning level. Any decrease of more than 20% required re-evaluation and the hip's extension degree was decreased.

According to the preoperative evaluation, first, the level of pedicle fracture was identified using fluoroscopy. A bilateral stab incision was performed at the vertebral level. Bilateral transpedicular placements of an 8 mm cannula into the vertebral body were performed under fluoroscopic guidance. Approval of the locations of the cannula was confirmed. Then from both sides of the vertebral level, each side was inserted with a balloon through the cannulas. The balloons were inflated separately, elevating the endplates and restoring vertebral body height. Afterward, the balloons were deflated and withdrawn, leaving a cavity within the vertebral body.

Then according to the preoperative evaluations, all the adjacent levels planned to be performed prophylactic vertebroplasty were also prepared. Bilateral stab incisions were performed to these adjacent levels and transpedicular placements of an 8 mm cannula into the vertebral bodies were performed under fluoroscopic guidance. Approval of the locations of the cannula was confirmed.

Ultimately, Polymethylmethacrylate (PMMA) bone cement was prepared. Mechanical aspiration of the vertebral bodies before administration of PMMA cement was done. First, the vertebral level with OVF co-existing with pedicle fractures was again inflated with a balloon. Immediately after inflation, the balloons were withdrawn after deflated, and mechanical aspiration was performed to this OVF level and all the prepared adjacent levels for prophylactic vertebroplasty followed by slow injection of a low viscosity cement of approximately 1 cc to each lumbar vertebra level and 0.8 cc to each thoracic vertebra level. The vertebral void was filled with the PMMA

cement. Fluoroscopy was used to confirm the restoration of the vertebral body height.

Afterwards, percutaneous pedicle screw insertion started using the standard technique which included opening an initial hole to the medial process of the pedicle and enlargement to the required diameter. Its trajectory was confirmed both anteroposterior and laterally. The marker was then malleted through the trajectory while visualizing via fluoroscopy. Taping was done smaller than the screw size to be used. Always a bigger diameter screw (7.5 mm) was used to acquire more purchases. A probe was used to control any perforation of the dural canal or extravertebral perforation. Afterward, a polyaxial pedicle screw mainly 6.5 mm in diameter was inserted into the thoracic vertebral bodies while a 7.5 mm pedicle screw was inserted into the lumbar vertebral bodies under image guidance. Lastly, the inserted TPF (fenestrated screw) was augmented with a 0.8 cc low viscosity cement injection slowly.

All the procedure was performed under continuous lateral fluoroscopy, alternating both pedicles by using 1 mL syringes simultaneously. Extravasation of the cement from the vertebral body was observed. Termination of the injection was planned whenever there was a presence of perivertebral cement migration.

Postoperative Evaluations

In the postoperative radiologic evaluations; to determine cement leakage, pedicle screw loosening (more than 2 mm halo sign around the screw), pull-out, migration, and fusion; a musculoskeletal radiologist assessed the patients' radiological data. In the early postoperative period, two patients underwent lung X-rays for cement embolism evaluation. These were evaluated by radiologists to investigate the presence of pulmonary cement embolism. Radiopaque images in the lung parenchymal greater than 1 mm were defined as cement embolism.

RESULTS

Thirty-two patients of OVF associated with pedicle fractures underwent vertebroplasty combined with TPF with a mean follow-up of 30 (24-74) months. Vertebroplasty combined with TPF was performed at the thoracolumbar spine in 21 patients, thoracic spine in 8 patients, and lumbar spine in 3 patients. All 32 patients had acute fractures at least at one level with only 8 patients having multilevel acute fractures. OVF cases without pedicle fracture treated with only vertebroplasty were performed at 26 levels. Prophylactic vertebroplasty was performed at 65 levels. In all these patients vertebroplasty combined with percutaneous TPF with fenestrated screw was performed at the acute fracture with only three patients undergoing two-level vertebroplasty combined with two-level percutaneous TPF (Figure 1 and 2). A total of 87 levels were performed vertebroplasty.

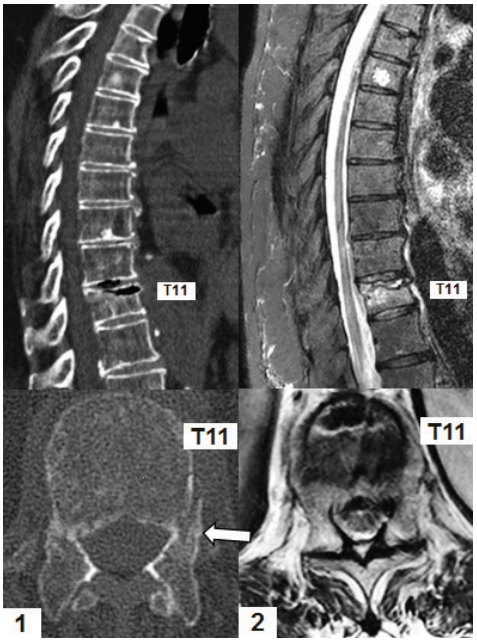

Figure 1. 1) Preoperative CT scan evaluations showing a T11 osteoporotic vertebra fracture demonstrating a vacuum cleft sign and superior endplate discontinuity extending to the posterior cortex may be associated with a pedicle fracture indicated with an arrow. 2) Preoperative MRI scan evaluations showing an acute T11 vertebral fracture
CT: Computerized tomography, MRI: Magnetic resonance imaging

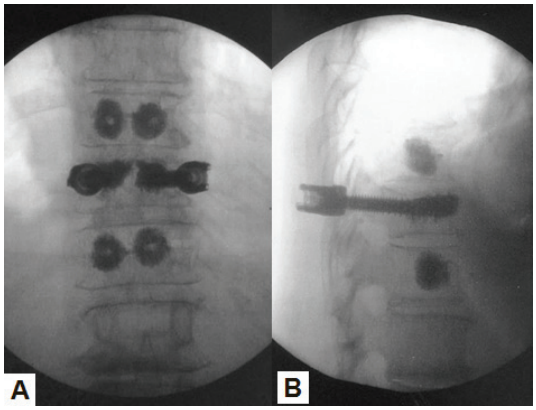

Figure 2. Intra-operative fluoroscopy images showing a single-level transpedicular screw fixation combined with vertebroplasty at the acute T11 vertebral fracture and prophylactic vertebroplasty to the adjacent levels. A) Demonstrating anterior-posterior view. B) Demostrating lateral view

Radiological Evaluations

All the radiological evaluations showed a mean vertebral body angle improvement of 20.9% and a mean local kyphosis angle improvement of 17.2%. The mean anterior vertebral height and posterior vertebral height increased by 13.5% and 3.5%, respectively after vertebroplasty (Figure 3) (Table 1).

Preoperative Quantative-CT analysis including bone mineral density and T-score mean values was 56.79 mg/cm^3 and

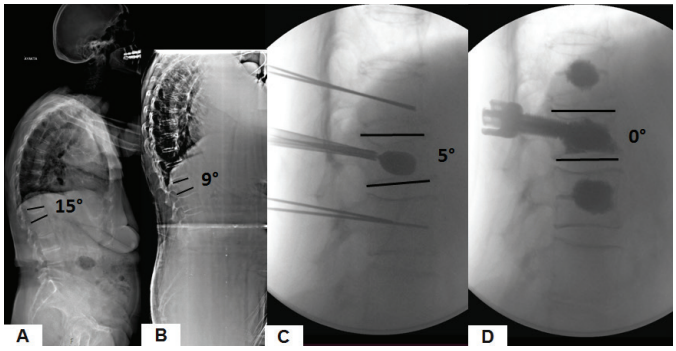

Figure 3. Preoperative standing lateral X-ray evaluation A) and lateral X-ray evaluation, B) taken in a prone position over Jackson table (Mizuho OSI) demonstrating an unstable fracture of L1 osteoporotic vertebra fracture with a vertebral body angle improving from 15° to 9°. C) Intraoperative lateral fluoroscopic evaluation demonstrating kyphosis reduction using balloon inflation at L1 fracture and transpedicular placements of cannulas to the adjacent levels (T12 and L2 vertebrae) for prophylactic vertebroplasty preparation. The balloon inflation improved the vertebral kyphosis from 9° B to 5° C. D) Intraoperative lateral fluoroscopic evaluation demonstrating vertebroplasty combined with bilateral transpedicular fixation of the fracture and prophylactic vertebroplasty at the adjacent levels. Balloon kyphoplasty restored the khyposis to 0°

Table 1. Radiological evaluations of the 32 elderly patients with OVF cases co-existing with PF

	Preoperative	Fup	Correction %
Vertebral body angle	9.4°	7.44°	-20.9
Bisegmental cobb angle	9.5°	7.87°	-17.2
AVH difference	15°	17.03°	13.5
PVH difference	21°	21.74°	3.5

PF: Pedicle fractures, OVF: Osteoporotic vertebral fractures, AVH: Anterior vertebral height, PVH: Posterior vertebral height

-4.38±0.538 respectively. The preoperative mean scores of visual analogue scale and Oswestry disability index were 7.63 and 60 respectively.

In the postoperative follow-up, none of the patients developed cement embolism nor had neurological deficits. Also, no pedicle screw pull-out was developed nor none of the patients developed vertebral collapse.

DISCUSSION

Vertebroplasty is the gold standard for treatment in elderly patients with OVF mainly used to reconstruct the fractured vertebrae. Different methods have been described to reconstruct the vertebra in the occurrence of a split fracture at the anterior column[10-13]. In the literature, treatment of osteoporotic fracture associated with pedicle fracture causing instability between the anterior and posterior column has not been described. Vertebroplasty combined with TPF using fenestrated screws is a new concept we defined to stabilize the two columns (anterior and posterior) in these unstable vertebral fractures by anchoring between them.

In a biomechanical study in which the thoracolumbar fracture models were established, the pedicle was indicated as a significant entity in terms of the mechanic stability, which supports especially the anterior column against the bear tension forces caused by forward bending when there is a bridge between anterior column and posterior ligamentous complex[14]. It was noted that the functional spinal units of the vertebra are subjected to massive compressive loads (preloads). The body weight passing through the anterior vertebra exerts a force on the instant center of rotation in the corpus, and to balance this enforcement in the anterior, the ligaments and muscles in the posterior administer balance out by applying compression force with the assistance of the momentum arm (pedicle), then, these two forces produce a force called the corpus preload, which is in the same direction as gravity. In the flexion state, the force arm of the body mass increases and the posterior structures balance out by generating more forces and leading to more preload. However, this preload in the flexion state is parallel to the gravity but not perpendicular to the corpus vertebrae. There is a separate force perpendicular and parallel to the corpus and this parallel force enforces the corpus forward to the translation; thus, the pedicle balances the force by acting as an anchor by connecting the corpus to the posterior[15].

When pedicle fractures and compression fractures coexist, they are generally considered as malignancy[16,17]. Nevertheless, in a radiological study by Ishiyama et al.[9], an edema in the pedicle was detected in 144 MRIs of 225 osteoporotic fractures (64%), whereby the pedicle fractures were identified in 45 patients on CTs[9]. Furthermore, some studies revealed that the pedicle fractures in compression fractures resulted in resistance to the conservative treatment methods and more collapse during follow-up[18,19].

Traditional vertebroplasty is critical in cases associated with pedicle fracture. Mechanical stability has always been emphasized by analyzing the anterior column whereby treatment techniques described have only involved reconstruction of the anterior column. However, the importance of the middle column is greatly underestimated. Also, the anterior column has been considered as the main load-bearing capacity of the vertebra. In the co-existence of pedicle fracture, only reconstructing the anterior column without any fixation of the pedicle eventually may produce a weak connection between the anterior and posterior columns. Hence, in patients with OVF accompanied by pedicle fracture when only treated with even a satisfactory vertebroplasty fragile vertebra still prevails which may eventually end up with vertebral collapse and splitting.

In 2014, Amoretti and Huwart[16] reported the data obtained after administering a screw system with bone cement under CT and fluoroscopy to 10 patients with split fractures on the vertebral body. In 2018, Cianfoni et al.[17] reported a new minimally invasive

internal fixation procedure in which the stenting/cementum complex on the corpus vertebrae with complex VCFs was fixed to the posterior vertebral elements with pedicle screws; the primary aim was to reconstruct the vertebrae by supporting the bone cement and the secondary aim was to provide bone integration with posterior structures using quite biocompatible titanium screws[11]. In 2019, the biomechanical study of the stent-screw-assisted augmentation technique was reported by La Barbera et al.[18] in which three groups were established as the osteoporotic vertebrae, percutaneous vertebroplasty, and stent-assisted augmentation[12]. The collapse and refracture were reported to be reduced in the screw group compared to the other groups since the tension in the anterior and medial column was significantly decreased in the vertebrae treated with stent-assisted augmentation.

In 2021, Yonezawa et al.[19] defined the vertebrae-pediculoplasty method as a new approach in osteoporotic vertebral fractures, in which cannulated screws are utilized with vertebroplasty. The method was recommended especially in the anterior and posterior split fractures that resulted in failures of the vertebroplasty and the advantage of this method was supporting the cement mass with screws from the lamina and pedicle. Additionally, in 2020 cement-screw system was utilized in Kummel's disease to reconstruct the anterior wall in 27 patients and stated their findings as convincing[13]. In our study, vertebroplasty combined with TPF provided stable fixation and prevented further vertebral collapse and splitting in all 32 patients with osteoporotic vertebra fractures associated with pedicle fractures. While using this novel surgical technique, we achieved recoveries in OVFs by ensuring compression to the pedicle fractures. Secondly, as these patients usually have kyphotic deformities, the body weight led to a forward pulling force on the corpus vertebrae, yet we prevented instability in the corpus by utilizing the pedicle screw functioning as an anchor. Thirdly, the pedicle screw in the cement served as a scaffold, allowing the axial loads in the corpus to be shared with the posterior column and protecting the vertebrae from new fractures in the medial column. Ultimately, this novel technique of vertebroplasty combined with TPF provided stable fixation and prevented a further vertebral collapse in all patients with osteoporotic vertebra fractures associated with pedicle fractures.

Study Limitations

Our study has many limitations. First, the patients included were elderly aged hence our mean follow-up was recorded short. Secondly, a relatively small number of patients was included in this novel technique study. Lastly, in this study a control group was not evaluated. Further studies are to be performed to compare patients treated with only vertebroplasty traditionally and those patients treated by combining vertebroplasty and percutaneous transpedicular fixation.

CONCLUSION

According to our study, vertebroplasty combined with TPF provided stable fixation and prevented a further vertebral collapse in all pts with osteoporotic vertebra fractures associated with pedicle fractures. Osteoporotic vertebra fractures having vacuum cleft sign or superior endplate discontinuity extending to the posterior cortex must be evaluated for the co-existence of a spontaneous pedicle fracture which causes instability and vertebral collapse. We recommend routine preoperative CT scan evaluation to determine the fracture pattern and check pedicle integrity in addition to MRI scans.

Ethics

Ethics Committee Approval: Ethical approval for this study was obtained from the İstanbul Bilim University Clinical Research Ethics Committee (approval number: 44140529/2016-06, date: 21/01/2016).

Informed Consent: Retrospective study.

Authorship Contributions

Surgical and Medical Practices: H.M.M., B.P., H.G., D.K., O.L.U., S.K., M.E., A.H., Concept: H.M.M., B.P., O.L.U., T.Ş., S.K., M.E., A.H., Design: H.M.M., H.G., D.K., T.Ş., S.K., M.E., A.H., Data Collection or Processing: H.M.M., B.P., H.G., O.L.U., T.Ş., M.E., A.H., Analysis or Interpretation: H.M.M., D.K., O.L.U., T.Ş., S.K., M.E., A.H., Literature Search: H.M.M., B.P., H.G., T.Ş., S.K., M.E., A.H., Writing: H.M.M., B.P., H.G., D.K., O.L.U., T.Ş., S.K., M.E., A.H.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study received no financial support.

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