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A Novel Bipedicular Dissociation Fracture Pattern of Vertebral Osteoporotic Fractures of the Elderly

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ABSTRACT

Introduction: CVFs are common, with several classification systems available. We have encountered osteoporotic vertebral fractures (OVFs) with PDF, a never-described fracture pattern.
This study evaluates this unique fracture's characteristics.

Methods: Retrospective study of surgically treated OVFs during 2016 to 2020.

Results: Of 105 patients, 85 had classifiable OVFs and 20 had uni-PDF (n = 10, 9.5%) or bi-PDF (n = 10, 9.5%). Both cohorts mainly had single vertebral fractures and upper end plate involvement with cleft sign found in 30% of PDFs versus 15.3% of OVFs ($P < 0.001$), higher incidence of burst fractures (40% vs. 25.9%; $P < 0.001$). Posterior vertebral body collapse was higher for PDFs (13.2 ± 9.3% vs. 18.3 ± 8.5%; $P = 0.02$). Most OVFs underwent balloon kyphoplasty (BKP) (94%). Most bi-PDFs were regarded unstable; six patients underwent PSF (2 short PSF, 1 PSF + BKP, and 3 BKP with intravertebral pedicular lag screws at the fractured vertebra). Half of the bi-PDFs underwent BKP-developed nonunion.

Conclusion: Our study is novel in describing an unrecognized OVF pattern disregarded in current classification systems. We found notable differences in fracture characteristics, prefracture functional status, and surgical results between OVF and PDF cohorts. We suggest adding this fracture pattern as a unique OF-4 subtype or a specific entity between OF-4 and 5, with uni-PDF as type A and bi-PDF as type B.

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Thoracolumbar fractures (TLFs) are a common spinal injury with specific biomechanical considerations, transitioning from rigid thoracic kyphosis to a mobile lumbar lordosis. Lesions at this level may have severe consequences, such as complete/partial cord or lower motor deficits, local pain, or kyphosis.[1-4] The incidence of traumatic TLF is variable and dependent on the region and country, ranging between 6.4 and 11.7 cases/million/year in the United States[2] with a global incidence of 3 cases/million/year, including osteoporotic fractures.[5] The treatment of

these fractures remains controversial. Historically, multiple classifications and scales have been devised to optimally define fracture patterns and guide treatment. These classifications and scales evolved, considering fracture morphology, mechanism, spinal stability, neurology, and posterior ligamentous complex integrity.[6-13] Despite the described evolution in TLF classifications, they did not encompass the rise of osteoporotic vertebral fractures (OVFs) that require a specific classification. Looking back, Nicoll described 166 TLFs in 152 miners in 1945,[14] Denis based his classification on 412 TLFs with an average age of 32.3 (17 to 75),[7] McCormack based the LSC on 28 patients ranging from 17 to 45 years,[9] and McAfee based his classification on 86 TLFs with an average age of 27.8.[15] Other classifications were made by expert opinion based on the previous classifications.[7,8,11,12] Noticing the inadequacy of current TLF classifications to address OVFs, Sugita et al[16] suggested a classification of vertebral compression fractures in the osteoporotic spine. Schnake et al[17] suggested the osteoporotic fracture classification (OF classification) with five subgroups: OF 1: no vertebral deformation; OF 2: deformation without or with only minor involvement of the posterior wall; OF 3: deformation with distinct involvement of the posterior wall; OF 4: loss of vertebral frame structure, vertebral body collapse, or pincer type fracture; and OF 5: injuries with distraction or rotation. Hao et al[18] published a classification system for chronic symptomatic osteoporotic thoracolumbar fracture (CSOTF) based on fracture morphology. All these OVF classifications describe degrees of vertebral body collapse but do not deal with posterior column injuries.

Bilateral pedicle fractures have been previously described sporadically. Several etiologies were described, bipedicular stress fractures after spinal instrumentation,[19] stress fractures in athletes,[20-22] and spontaneous fatigue fractures.[23-28] These case studies or case reports described a rare fracture pattern, hypothesizing it to be stress-related because no prefracture trauma was recorded.

In our spinal surgery practice, we have encountered osteoporotic vertebral fractures with concomitant bipedicular dissociation fractures (Figure 1). Referring to these acute fractures as the rare stress fractures previously described is wrong because of different etiologies and different fracture patterns. According to the TLF classifications, these fractures are considered unstable because they dissociate the middle and posterior columns. Since this fracture pattern, a bipedicular fracture with a concomitant vertebral body compression fracture was never described, this study aims to evaluate this unique fracture's epidemiology, mechanism, morphology, clinical implications, and treatment options.

Methods

A retrospective study including all patients treated surgically by the Orthopedic Surgery Department for Osteoporotic Thoracolumbar Vertebral Compression fractures during 2016 to 2020. The inclusion criteria were patients aged 65 years or older and compatible with the NICE (The National Institute for Health and Care Excellence) guidelines.[29] All patients underwent

Figure 1

Spine radiographs of osteoporotic vertebral fractures with concomitant bipedicular dissociation fractures. **A**, Axial view. **B**, Left pedicle on sagittal view. **C**, Right pedicle on sagittal view.

physical examination and were found to be suffering local pain on percussion over the fractured vertebra. Fractures were proved by at least two imaging modalities: x-rays, supine and standing when possible, and CT scans. MRI was not used routinely.

Surgical treatment was offered for intractable pain, progressive fracture collapse, lack of union (ascertained by a cleft sign under the vertebral end plate on CT or MRI), or when fractures were deemed unstable by the TLICS or AO classifications.

Exclusion criteria included osteomyelitis, history of malignancy, and previous thoracolumbar surgery. Patients treated conservatively (Analgesics, Jewett Brace, and Activity modification for 2 months followed by physiotherapy and osteoporosis work-up) were excluded from this study because of limited and partial follow-up and incomplete imaging data.

Data collected included the patient's demographic data, time from fracture to surgery, prefracture function level, mechanism of trauma, neurologic status, fracture level, fracture morphology (end plate involvement, pedicular involvement, characteristics of a burst fracture, and a cleft sign), type of surgery performed, and length of gait in the first postoperative physiotherapy session. Two independent fellowship-trained senior spine surgeons assessed all CT scans and measured the percentage of anterior and posterior vertebral body collapse; the expected height of the fractured vertebra was calculated as the average height of the vertebra cephalic and caudal to the fractured vertebra. When vertebrae around the fractured vertebra seemed deformed, the less deformed vertebra was considered the reference vertebra.

Study data statistical analyses were done using SPSS 20.0. Difference between pretreatment and posttreatment was calculated using the Student *t*-test. Categorical parameters were assessed using the Chi-square test.

Results

During the study period, 2016 to 2020, one hundred five patients fulfilled the study's inclusion criteria and were treated surgically by the Orthopedic Surgery Department for Thoracolumbar Osteoporotic Vertebral fractures. These 105 patients had 140 fractured vertebrae. Eighty-five patients had osteoporotic vertebral fractures classifiable by the OF or CSOTF classifications, comprising the OVF cohort, while 20 patients had unipedicular (10 patients, 9.5%) or bipedicular (10 patients, 9.5%) dissociation fractures, unclassifiable by the current fracture classification systems (Figure 1). In both cohorts, OVF and pedicular dissociation fractures, the average age was 78 ± 7.6 and 79.8 ± 7.9 ($P = 0.52$), respectively, and most patients were female, 78.8% and 60% ($P = 0.13$), respectively (Table 1). Height, weight, and BMI were similar between cohorts ($P > 0.05$) (Table 1). The days from fracture to surgery were similar between the cohorts, with an average of 22.2 ± 34.5 days.

The prefracture function was significantly better in the OVF cohort than in the pedicular dissociation cohort, with 58.8% versus 20% of independent patients, 14.1% versus 15% needing a walker, and 24.7% versus 50% needing a caregiver's assistance, respectively ($P = 0.004$). 10% of the pedicular dissociation cohort was utterly dependent on a caregiver for activities of daily living, compared with 2.4% of the OVF cohort, and an additional 5% were wheelchair user (Table 1).

Most of the patients in the OVF and pedicular dissociation cohorts sustained a fall as a cause of the vertebral fracture, 67.1% and 85%, respectively, while 30.6% and 15%, respectively, had a spontaneous nontraumatic vertebral fracture, $P = 0.268$ (Table 1). Only a minority of the OVF cohort was involved in a motor vehicle accident, 2.4%.

OVF fracture dispersion was from the T7 vertebra to L5, mainly around the thoracolumbar junction (T11-L2; Figure 2). Bipedicular dissociation fractures involve the thoracolumbar spine, from T11 to L5, with the highest incidence in the L3 vertebra (Figure 2), while unipedicular fractures mainly involve the T12-L1 vertebrae. For both cohorts, 81% of the patients had a single vertebral fracture, 11.4% suffered from two fractured vertebrae, 2.9% had three and four fractured vertebrae, and 1.9% had five concomitant vertebral fractures on hospitalization. 17 of the pedicular dissociation fractures were single vertebral fractures, while three patients had concomitant two fractured vertebrae of which one vertebra was OVF and the other a pedicular dissociation fracture.

OVFs and pedicular dissociation fractures showed similar upper end plate dominant involvement, followed by upper and lower end plate involvement (Table 1). 30% of the pedicular dissociation fractures had a cleft sign, while only 15.3% of OVFs had a cleft sign ($P < 0.001$; Table 1). Pedicular dissociation fractures had a significantly higher incidence of burst fractures than OVFs, 40% versus 25.9%, respectively ($P < 0.001$; Table 1).

OVFs had the same percentage of preoperative anterior vertebral body collapse as pedicular dissociation

Table 1. Patients Cohort Demographics

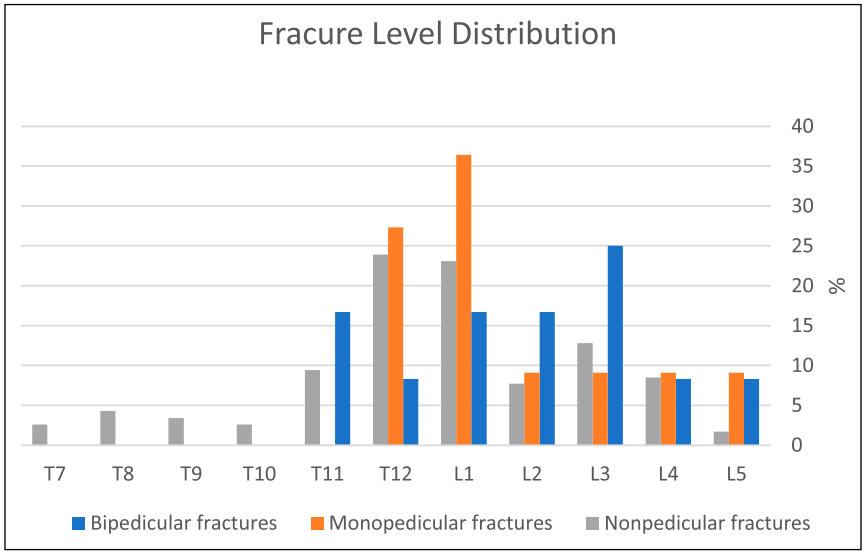
Cohort Characteristics	OVF (n = 85)	Pedicular dissociation (n = 20)	*P*
Age (y)	78 ± 7.6	79.8 ± 7.9	0.52
Sex (female)	78.8%	60%	0.13
Height (m)	1.6 ± 0.1	1.6 ± 0.1	0.81
Weight (kg)	68.2 ± 14.3	68.5 ± 15.1	0.94
BMI	26.5 ± 5	26.2 ± 5.6	0.88
Fracture mechanism			
Spontaneous	30.6%	15%	0.268
Fall	67.1%	85%	
Motor vehicle accident	2.4%	0	
Days from fracture to surgery	20.6 ± 36.1	29.7 ± 24.6	0.32
Prefracture function			
Independent	58.8%	20%	0.004
Walker	14.1%	15%	
Partial assistance	24.7%	50%	
Wheelchair user	0%	5%	
Full assistance	2.4%	10%	
Fracture morphology			
Upper end plate involvement	63.5%	60%	0.70
Lower end plate involvement	4.7%	0%	
Both end plate involvement	31.8%	40%	
Cleft sign	15.3%	30%	<0.001
Burst fracture	25.9%	40%	<0.001
% posterior vertebral body collapse	13.2 ± 9.3	18.3 ± 8.5	0.02
% anterior vertebral body collapse	26.8 ± 16.2	25.9 ± 17.6	0.99
Surgery			
Balloon kyphoplasty (BKP)	94%	55%	<0.001
Posterior spinal fusion (PSF)	0%	15%	
PSF + BKP	6%	30%	
Postoperative gait distance (m)	15.3 ± 7.6	12.3 ± 7	0.16
Postoperative discharge destination			
Home	62.4%	40%	0.08
Rehabilitation center	31.8%	50%	
Other medical department	4.7%	10%	0.365
In-hospital mortality	1.2%	0%	

PSF = posterior spinal fusion, BKP = balloon kyphoplasty

fractures, 26.8 ± 16.2% versus 25.9 ± 17.6%, respectively ($P = 0.99$), while the percentage of posterior vertebral body collapse was significantly higher for the pedicular dissociation fractures, 13.2 ± 9.3% versus 18.3 ± 8.5%, respectively ($P = 0.02$; Table 1).

In our cohort, OVFs were mainly treated by balloon kyphoplasty (BKP; 94%), while some burst fractures were treated by a short open or percutaneous posterior fixation (PSF) combined with BKP for anterior body support of the fractured vertebra (6%). In our retrospective cohort, 10 unipedicular dissociation fractures were deemed stable: Seven patients underwent BKP, two underwent short posterior spinal stabilization combined with BKP, and one underwent short percutaneous

Figure 2



Graph showing fracture distribution by the level of osteoporotic vertebral fractures with concomitant bipedicular dissociation fractures.

posterior stabilization. None of the unipedicular fracture patients required additional surgery on a 1-year follow-up. The bipedicular dissociation fractures were generally regarded as unstable, and six patients underwent posterior spinal fusion: Two underwent a short PSF, one underwent PSF and BKP, and three underwent BKP with

Figure 3

Diagram showing balloon kyphoplasty with intravertebral fusion (pedicular screws at the level of the fractured vertebra). **A**, Sagittal view. **B**, Coronal view.

intravertebral fusion (pedicular screws at the level of the fractured vertebra (Figure 3)). No complications were noted in a 1-year follow-up in these six spinal stabilization patients. Four bipedicular dissociation fractures underwent BKP of which two developed nonunion of their bipedicular dissociation fracture, as diagnosed by CT a year after surgery (Figure 4); none required revision surgery.

After surgery, OVF and pedicular dissociation fracture cohorts gained similar immediate gait ability using a walker under a physiotherapist's supervision and assistance, 15.3 ± 7.6m and 12.3 ± 7m, respectively (P = 0.16). Most of the OVF cohort were discharged home, 62.4%, while only 40% of the pedicular dissociation fracture cohort were discharged home, and 50% were discharged to a rehabilitation center. This difference showed a trend, P = 0.08, not reaching statistical significance due to the cohorts' sizes.

Discussion

Thoracic and lumbar fractures (TLF) are a common spinal injury with specific biomechanical considerations, transitioning from rigid thoracic kyphosis to a mobile lumbar lordosis. Historically, multiple classifications and scales have been devised to optimally define fracture patterns and guide treatment. These classifications and scales evolved, considering fracture morphology, mechanism, spinal stability, neurology, and posterior ligamentous complex integrity.[11] Noticing the inadequacy of current TLF classifications to address OVFs, Sugita et al[16] suggested a classification of vertebral compression fractures in the osteoporotic spine. Schnake et al [17] and Hao et al[18] proposed other osteoporotic fracture classifications, but these OVF classifications describe degrees of vertebral body collapse but do not deal with posterior column integrity. Bilateral pedicle fractures have been previously described sporadically, usually classified as stress-related fractures. Several etiologies were described bipedicular stress fractures after spinal instrumentation,[19] stress fractures in athletes,[20-22] and spontaneous fatigue fractures.[23-28] These case studies or case reports described a rare fracture pattern, hypothesizing it to be stress-related because no prefracture trauma was recorded. By contrast, this study evaluated the clinical and radiological outcomes of 105 patients surgically treated for thoracolumbar osteoporotic vertebral fractures between 2016 and 2020, comparing the characteristics and management of osteoporotic vertebral fractures (OVFs)

Figure 4

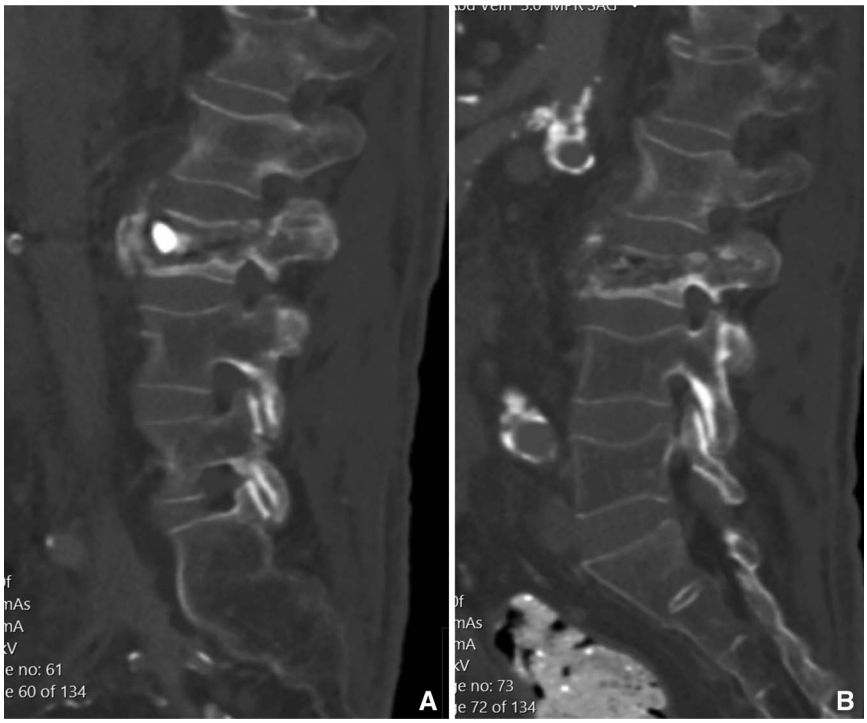


Diagram showing nonunion of bipedicular dissociation fracture, as diagnosed by CT a year after surgery. **A**, Left pedicle on sagittal view. **B**, Right pedicle on sagittal view.

and pedicular dissociation fractures, a newly described fracture pattern. Our results indicate notable differences between the two cohorts in fracture characteristics, prefracture functional status, and surgical management. In our study, bipedicular dissociation fractures constituted 9.5% of the OVFs reaching surgery, a notable OVF subgroup that remains unclassified by the current classification systems.

OVF and pedicular dissociation fracture cohorts were predominantly female and elderly, with similar ages, heights, weights, and BMI. This finding is consistent with previous literature, highlighting the prevalence of osteoporotic fractures among older people, especially women.[1-5] The time from fracture to surgery was similar between the cohorts, reflecting the time frame of surgical intervention in managing these fractures.

Notably, the prefracture functional status was markedly better in the OVF cohort than in the pedicular dissociation cohort. The greater dependence on caregivers and mobility aids in the pedicular dissociation cohort suggests a higher burden of disability in this patient population. This difference in functional status may have implications for postoperative recovery, rehabilitation, and discharge planning.

Most patients in both cohorts sustained fractures due to a fall, with a lower proportion of spontaneous nontraumatic vertebral fractures, suggesting that the bipedicular dissociation fractures, as osteoporotic vertebral compression fractures, can be traumatic or an osteoporotic pathological fracture. This finding emphasizes the importance of fall prevention measures for patients with osteoporosis.

The distribution and morphology of fractures differed between OVF and pedicular dissociation cohorts, with OVF fractures primarily located around the thoracolumbar junction and pedicular dissociation fractures involving the lower thoracic and lumbar vertebrae, mainly T11-L3. Notably, pedicular dissociation fractures had a higher incidence of burst fractures and cleft signs, which may indicate a more severe injury pattern and greater instability than OVFs, parameters not included in current OVF classification systems.[16-18] OVFs had the same preoperative percentage of anterior vertebral body collapse as pedicular dissociation fractures, 26.8 ± 16.2% versus 25.9 ± 17.6%, respectively (P = 0.99), while the percentage of posterior vertebral body collapse was significantly higher for the pedicular dissociation fractures, 13.2 ± 9.3% versus 18.3 ± 8.5%, respectively (P = 0.02; Table 1). This may explain the fracture mechanism; as the upper posterior vertebral body collapses, the pedicles are fractured and dissociated from the vertebral body, separating the fractured anterior and middle columns from the posterior column and causing vertebral instability as defined by Dennis.[7]

The surgical management of OVFs and pedicular dissociation fractures also differed. OVFs were primarily treated with balloon kyphoplasty (BKP). At the same time, pedicular dissociation fractures required a more diverse range of stabilization techniques, including short posterior spinal fusion (PSF), BKP combined with PSF, or intravertebral fixation combining pedicular lag screws with BKP. Four cases of bipedicular fractures underwent BKP without additional stabilization, resulting in 50% of fracture nonunion. This finding suggests that pedicular dissociation fractures may present more notable surgical challenges due to their inherent instability and complexity. Additional research is needed to optimize the surgical management of these fractures and minimize complications such as nonunion, seen in half of the patients who underwent BKP for bipedicular dissociation fractures.

Postoperatively, both cohorts gained similar immediate gait ability under physiotherapist supervision, indicating comparable short-term functional recovery. However, there was a trend toward a higher proportion of pedicular dissociation patients being discharged to rehabilitation centers, which may reflect the poorer prefracture functional status and increased disability in this population. This trend did not reach statistical significance, possibly due to the small sample size of the cohorts, and additional investigation with larger sample sizes is warranted.

After the demographic, etiological, morphologic, and treatment description of bipedicular dissociation vertebral fractures, these fractures should be included in the OF classification[17] as part of the OF four subtypes because they are closer to the definition of loss of vertebral frame structure and pincer type fractures than the OF five injuries of distraction or rotation.

Our study has several limitations, including its retrospective nature, relatively small sample size, and single-center setting. In addition, we did not evaluate long-term functional outcomes or quality-of-life measures. Future prospective, multicenter studies with larger patient cohorts and long-term follow-up are needed to confirm our findings and assess the effect of different surgical approaches on patient outcomes and quality of life.

Conclusion

Our study is novel in describing an osteoporotic fracture pattern unrecognized previously and disregarded

in current OVF fracture classification systems. We found notable differences in fracture characteristics, prefracture functional status, and surgical management between OVF and pedicular dissociation fracture cohorts. Additional research is needed to optimize the surgical management of these fractures, and clinicians should consider the pedicular dissociation fracture morphology and contemplate fracture stability, especially with bipedicular vertebral dissociation, when planning surgical interventions for thoracolumbar osteoporotic vertebral fractures. We suggest adding this fracture pattern as a unique subtype of OF-4 or a specific entity between OF-4 and 5, with unipedicular dissociation as type A and bipedicular as type B. Additional studies with larger cohorts are warranted.

References

1. Sharif S, Shaikh Y, Yaman O, Zileli M: Surgical techniques for thoracolumbar spine fractures: WFNS spine committee recommendations. *Neurospine* 2021;18:667-680.

2. Hu R, Mustard CA, Burns C: Epidemiology of incident spinal fracture in a complete population. *Spine* 1996;21:492-499.

3. Li B, Sun C, Zhao C, et al.: Epidemiological profile of thoracolumbar fracture (TLF) over a period of 10 years in Tianjin, China. *J Spinal Cord Med* 2019;42:178-183.

4. Leucht P, Fischer K, Muhr G, Mueller EJ: Epidemiology of traumatic spine fractures. *Injury* 2009;40:166-172.

5. Zileli M, Sharif S, Fornari M: Incidence and epidemiology of thoracolumbar spine fractures: WFNS spine committee recommendations. *Neurospine* 2021;18:704-712.

6. Böhler L: *Die Technik der Knochenbruchbehandlung im Frieden und im Kriege*, 9-11. Wien: Maudrich, 1943.

7. Denis F: The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. *Spine* 1983;8:817-831.

8. Holdsworth F: Fractures, dislocations, and fracture-dislocations of the spine. *J Bone Joint Surg Br Vol* 1963;45-B:6-20.

9. McCormack T, Karaikovic E, Gaines RW: The load sharing classification of spine fractures. *Spine* 1994;19:1741-1744.

10. Magerl F, Aebi M, Gertzbein SD, Harms J, Nazarian S: A comprehensive classification of thoracic and lumbar injuries. *Eur Spine J*1994;3:184-201.

11. Vaccaro AR, Lehman RA Jr, Hurlbert RJ, et al.: A new classification of thoracolumbar injuries: The importance of injury morphology, the integrity of the posterior ligamentous complex, and neurologic status. *Spine* 2005; 30:2325-2333.

12. Reinhold M, Audigé L, Schnake KJ, Bellabarba C, Dai LY, Oner FC: AO spine injury classification system: A revision proposal for the thoracic and lumbar spine. *Eur Spine J* 2013;22:2184-2201.

13. Vaccaro AR, Schroeder GD, Kepler CK, et al.: The surgical algorithm for the AOSpine thoracolumbar spine injury classification system. *Eur Spine J*2016;25:1087-1094.

14. Nicoll E: Fractures of the dorso-lumbar spine. *J Bone Joint Surg Br Vol* 1949;31B:376-394.

15. McAfee PC, Yuan HA, Fredrickson BE, Lubicky JP: The value of computed tomography in thoracolumbar fractures. An analysis of one hundred consecutive cases and a new classification. *J Bone Joint Surg Am Vol* 1983;65:461-473.

16. Sugita M, Watanabe N, Mikami Y, Hase H, Kubo T: Classification of vertebral compression fractures in the osteoporotic spine. *J Spinal Disord Tech* 2005;18:376-381.

17. Schnake K, Bouzakri N, Blattert T, et al.: Validation of a classification system for osteoporotic thoracolumbar fractures (OF-classification). *Eur Spine J* 2014;23:2511.

18. Hao D-J, Yang JS, Tuo Y, et al.: Reliability and application of the new morphological classification system for chronic symptomatic osteoporotic thoracolumbar fracture. *J Orthop Surg Res* 2020;15:348-410.

19. Ha K-Y, Kim Y-H: Bilateral pedicle stress fracture after instrumented posterolateral lumbar fusion: A case report. *Spine* 2003;28:E158-E160.

20. Amari R, Sakai T, Katoh S, et al.: Fresh stress fractures of lumbar pedicles in an adolescent male ballet dancer: Case report and literature review. *Arch Orthop Trauma Surg* 2009;129:397-401.

21. Ireland ML, Micheli L: Bilateral stress fracture of the lumbar pedicles in a ballet dancer. A case report. *J Bone Joint Surg Am volume* 1987;69:140-142.

22. Parvataneni HK, Nicholas SJ, McCance SE: Bilateral pedicle stress fractures in a female athlete: Case report and review of the literature. *Spine* 2004;29:E19-E21.

23. Doita M, Shimomura T, Nishida K, Maeno K, Fujioka H, Kurosaka M: Bilateral pedicle stress fracture in a patient with lumbar spinal stenosis: A case report. *J spinal Disord Tech* 2008;21:531-534.

24. Han S-H, Hyun SJ, Jahng TA, Kim KJ: Posterior osteosynthesis of a spontaneous bilateral pedicle fracture of the lumbar spine. *J Neurosurg Spine* 2016;24:398-401.

25. Johnson JN, Wang MY: Stress fracture of the lumbar pedicle bilaterally: Surgical repair using a percutaneous minimally invasive technique. *J Neurosurg Spine* 2009;11:724-728.

26. Kim HS, Kim SW, Lee WT: Spondylolisthesis accompanying bilateral pedicle stress fracture at two vertebrae. *J Korean Neurosurg Soc* 2012;51:388-390.

27. Sadiq M: Bilateral pedicle stress fracture in the lumbar spine of a sedentary office worker. *Eur Spine J* 2006;15suppl 5:653-655.

28. Schmid T, Heini P, Benneker L: A rare case of non-traumatic, multi-level, bilateral pedicle fractures of the lumbar spine in a 60-year-old patient. *Eur Spine J* 2017;26suppl 1:197-201.

29. 2013, N.I.f.H.a.C.E.: *Percutaneous vertebroplasty and percutaneous balloon kyphoplasty for treating osteoporotic vertebral compression fractures*. London, UK National Institute for Health and Care Excellence, 2013.