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Case Report

Spinal Endoscopy-Targeted Bone Grafting for the Vertebral “Shell” Phenomenon: A Case Report

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Abstract

In thoracolumbar burst fractures, internal fixation using the distraction reduction screw–rod system via the posterior approach can result in a “shell” in the vertebral body. This “shell” is difficult to detect via intraoperative fluoroscopy and is generally detected during postoperative follow-up imaging. The high incidence of such “shell” is a critical factor resulting in serious complications, including vertebral collapse, nonunion, and internal fixation failure. However, no standardized clinical treatment has been identified for this “shell” phenomenon. Herein, we report the case of a patient who presented with low back pain and discomfort after developing a nonunion owing to the “shell” in the lumbar 3 vertebral body 14 months after internal fixation of a lumbar fracture. The patient underwent spinal endoscopy-targeted bone grafting via superior pedicle notch approach. The patient’s low back pain was relieved one month postoperatively and the internal fixation device was removed at 9 months postoperatively after bony healing of a fracture of the lumbar 3 vertebrae. This procedure can effectively support the anterior middle column and promote vertebral fracture healing and is minimally invasive, precise, safe, and effective; therefore, we recommend this novel procedure for the “shell” phenomenon surgery for lumbar vertebral fractures.

Keywords: Bone graft; Bone nonunion; “Shell” phenomenon; Spinal endoscopy; Thoracolumbar vertebral fracture

Abbreviations: **CT:** Computed Tomography; **PVP:** Percutaneous Vertebroplasty; **3D:** Three Dimensional

Introduction

Thoracolumbar fractures are a common type of spinal fracture, accounting for 70% of cases; among them, thoracolumbar burst fractures account for approximately 10%–20% of cases [1]. When individuals with thoracolumbar burst fractures undergo internal fixation with the distraction reduction screw–rod system via the posterior approach, the intravertebral trabecular scaffold structure can get damaged because of severe compression fracture of the vertebral body. Although the height of the vertebral body is restored after reduction, its skeletal structure is not, resulting in the formation of a bone defect area within the vertebral body, which is called the “shell” phenomenon. This “shell” phenomenon has a high incidence of approximately 52%–100% and is an unpredictable preoperative event, further increasing the incidence of associated complications, including vertebral collapse, height loss, internal fixation failure, and nonunion [1-3]. Moreover, the clinical treatment modalities and filler material selection are controversial, leading to the absence of a standardized treatment strategy [2,3]. To the best of our knowledge, to date, no study has reported the treatment of the vertebral “shell” using spinal endoscopy-targeted bone grafting via superior pedicle notch approach. Herein, we report for the first time a case of non-union of a fracture caused by a “shell” of the lumbar 3 vertebrae, who underwent targeted removal of a “shell” lesion in the lumbar 3 (L3) vertebral body and bone grafting using the abovementioned approach. Furthermore, we conducted a retrospective analysis of the treatment strategies for this “shell” phenomenon after the internal fixation of a vertebral fracture.

Case presentation

Presentation and Examination

A 52-year-old woman working as a construction worker injured herself at work because of a heavy object, resulting in burst fractures in the L2 and L3 vertebrae and spinal cord injury (Figure 1). The patient developed weakness and numbness in her lower extremities. Subsequently, she underwent internal fixation using the distraction reduction screw–rod system via the posterior approach and articular eminence and intertransverse process bone grafting and fusion. Computed Tomography (CT) performed 2 days postoperatively revealed that the height of the L3 vertebra was restored; however, a "shell" had formed (Figure 2a-c). At 1 month postoperatively, the muscle strength and tone of the patient gradually recovered and she was able to walk normally. However, at 14 months postoperatively, the patient was readmitted to the hospital owing to low back pain and numbness in the lateral calf of the right lower extremity. CT of the lumbar spine (Figure 2d-f) revealed a slight reduction of the "shell" in the L3 vertebral body compared with its previous state, but with a large "shell" with sclerotic edges and vertebral nonunion. The pain and discomfort in the lower back of the patient were because of this nonunion, decreasing the likelihood of continued fracture healing and increasing the risk of serious complications such as post-traumatic delayed vertebral body collapse and internal fixation failure. Therefore, the patient underwent spinal endoscopy-targeted bone grafting via the superior pedicle notch approach.

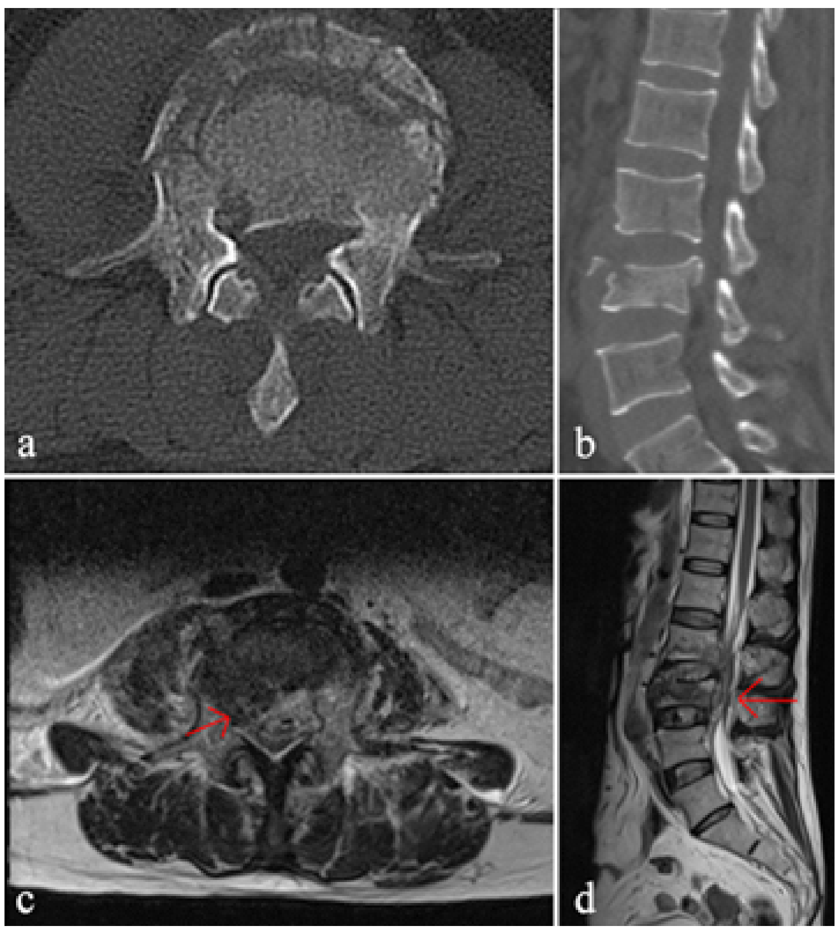

Figure 1: Preoperative CT and MRI imaging examinations. (a-b) Preoperative CT and MRI showed L2, L3 burst fracture, L3 secondary spinal stenosis, cauda equina damage(red arrows represent spinal nerve damage).

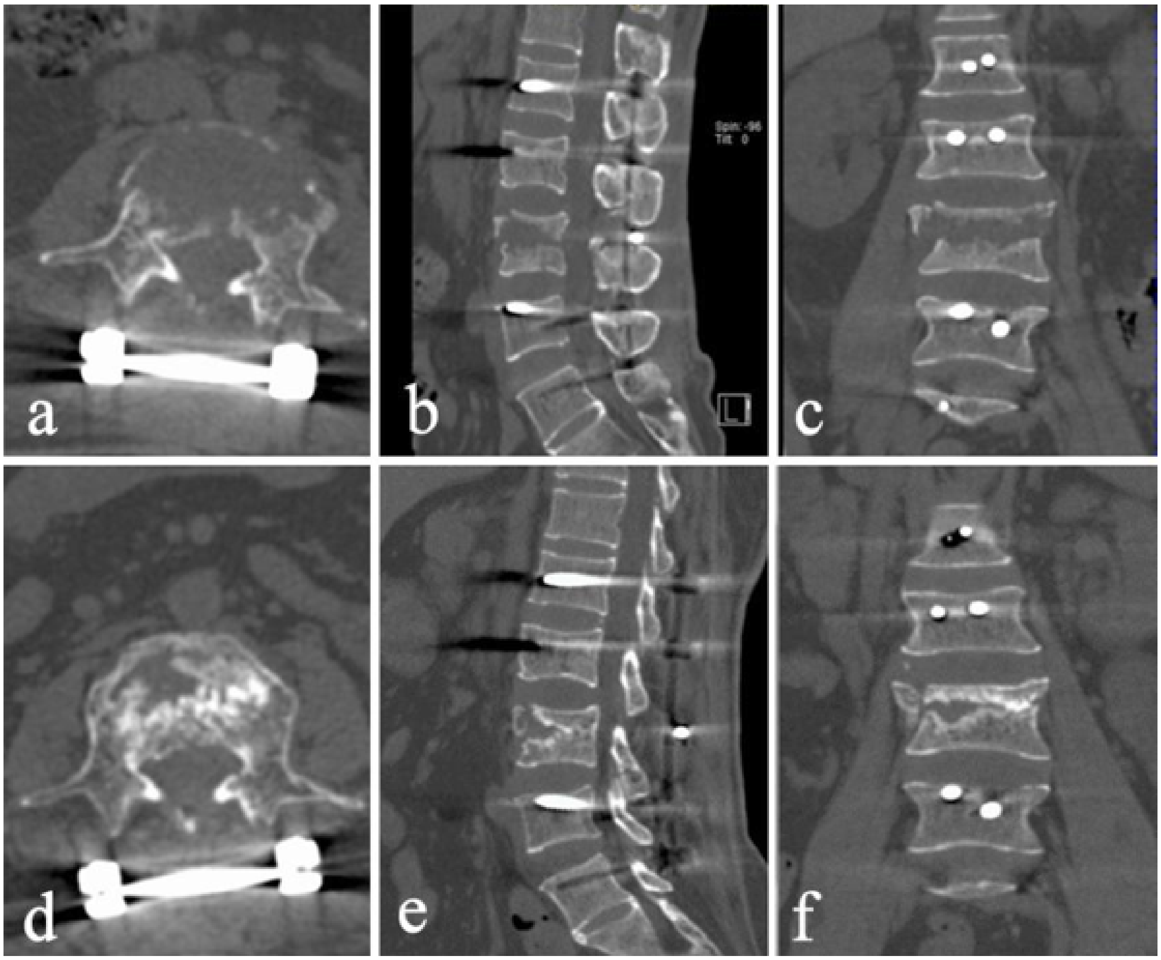

Figure 2: Repeat CT after lumbar fracture via posterior reduction and internal fixation. (a-c) The patient's vertebral body height was restored at the 2-day postoperative review, but there was a large bone defect in the lumbar 3 vertebral body, i.e., the vertebral body "shell" phenomenon; (d-f) at the 14-month postoperative review, there was no change in the size of the vertebral body shell, and the bone at the edge of the shell hardened, and the fracture still did not heal.

Demonstration of Surgical Technique

The surgery was done under general anaesthesia with strict aseptic precautions. Based on the preoperative three-dimensional CT model of the L3 vertebral body of the patient, the targeted puncture was performed using the superior pedicle notch approach (Figure 3a,b), which accurately reached the "shell" lesion in the L3 vertebral body and verified the safety and feasibility of this approach. Before surgery, using C-arm fluoroscopy, the skin puncture entry point of the right intervertebral foramen in L2/3 (Figure 3 c1) and the right body projection of the vertebral body (Figure 3 c2) were located and marked. The puncture point was marked 6 cm from the midline of the right lumbar spine using a surgical marker for the iliac bone (Figure 3 c3). After routine disinfection and surgical drape placement, a puncture needle was used to penetrate the right superior pedicle notch of the L3 vertebra; then, a guide wire was placed after needle removal. After a skin incision of 0.7 cm, a Tom needle was punctured through the subvertebral pedicle incisure to reach the nonunion vertebral space, where the fluoroscopic position was satisfactory (Figure 3d). The placed guide wire and a bone drill were steadily used to access the nonunion L3 vertebral space. Thereafter, a working access sleeve and an intervertebral foraminoscope were used to remove hyperplastic scar tissues and sclerotic lesions from the nonunion vertebral space until fresh blood exuded from the bone surface (Figure 3e,f). Subsequently, the intervertebral foraminoscope was withdrawn and the working sleeve was kept in reserve. Bone fragments of appropriate sizes were prepared using the right iliac crest bone, implanted along the working sleeve, and tamped with a bone grafting rod to appropriately implant the bone and fill the vertebral "shell". Lumbar CT at 1 day postoperatively indicated adequate bone grafting in the L3 vertebral "shell" (Figure 4a-c). Back pain alleviated at 1 months post-grafting. At 9 months postoperatively, a follow-up CT examination showed bony filling in the "shell" of the lumbar 3 vertebrae, sclerosis of the border between the implant particles and the "shell", and the lumbar 3 vertebral fracture healed bony, and the internal fixation device of the lumbar nail-rod system was surgically removed (Figure 4d-f).

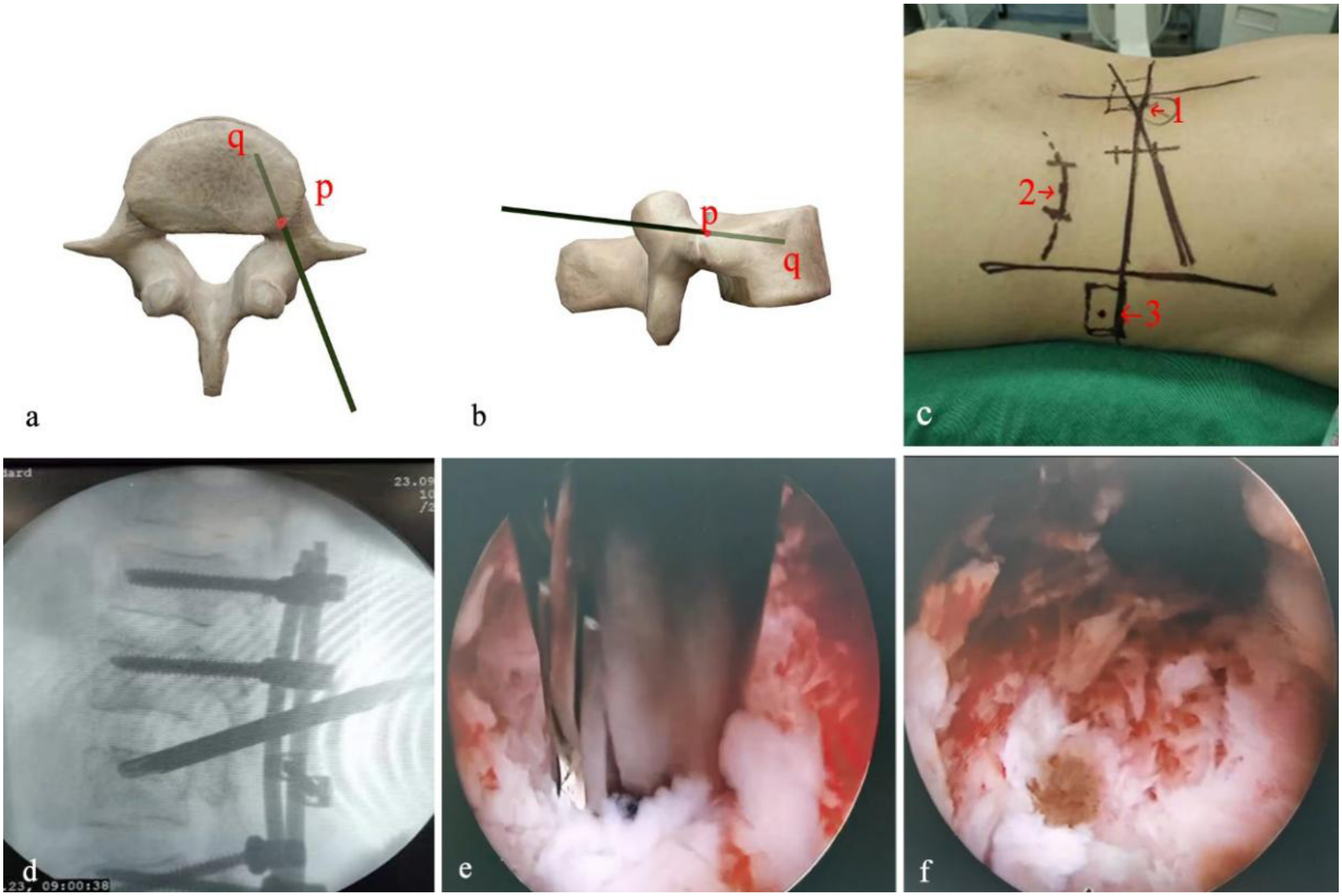

Figure 3: Diagram of the surgical approach and intraoperative maneuvers. (a, b) Three-dimensional simulation diagram of the lumbar 3 vertebral body via the superior pedicle notch approach, point p is the bone entry point of the suprapedicle notch; point o is the location of the lesion; (c) X-ray and mark the skin puncture point (c1) and the body surface projection (c3) of the 3rd lumbar vertebra on the right side, marked with the ilium surgical marker line (c2); (d) The Tom needle enters the vertebral body through the superior pedicle notch to reach the nonunion "shell" of the vertebral body; (e, f) Insert the intervertebral foramenoscope through the working channel to remove the hypertrophic scar tissue in the nonunion space of the vertebral body, and remove the sclerotic lesions in the vertebral body until fresh blood seeps out of the bone surface.

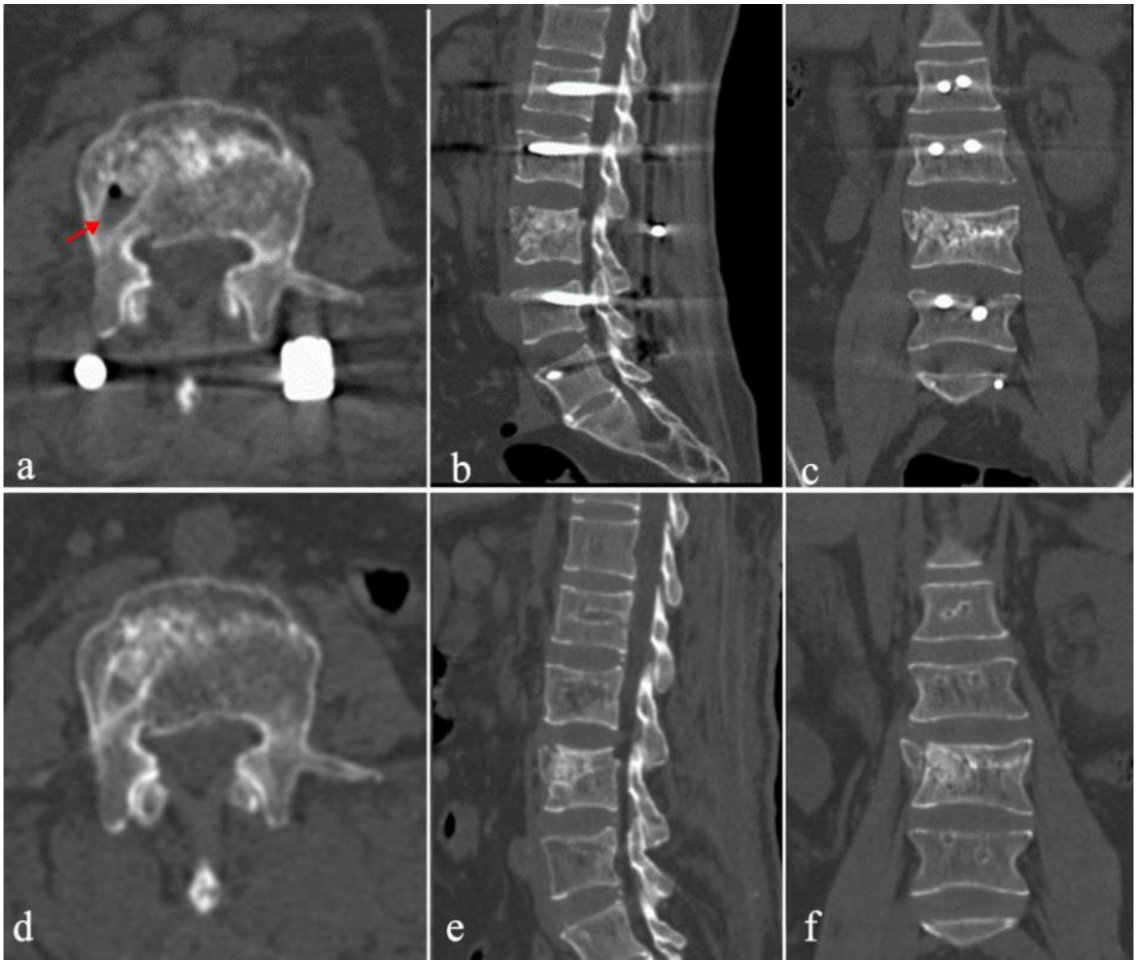

Figure 4: Repeat CT after spinal endoscopic bone grafting. (a-c) The postoperative review 2 days later showed adequate bone grafting in the lumbar 3 vertebral body "shell", and the red arrow represents the bone graft channel. (d-f) At 9 months postoperatively, the CT examination showed bony filling in the "shell" of the lumbar 3 vertebrae, sclerosis of the border between the implant particles and the "shell", and the lumbar 3 vertebral fracture healed bony, and the internal fixation device of the lumbar nail-rod system was surgically removed vertebral body.

Discussion

The primary reasons for the vertebral "shell" phenomenon include severe compression fractures (>50% compression), compromised disc integrity, intraoperative overdistraction, failure of nail placement in the injured vertebra, and osteoporosis [1-3]. In the present case, the patient presented with the abovementioned features. Furthermore, she developed a "shell" in the L3 vertebral body at 14 months postoperatively, which resulted in nonunion and subsequent low back pain and discomfort. A biomechanical study [4] has reported that the anterior and middle columns of the vertebral body carry 80% of the weight bearing for spinal stability, whereas the posterior column carries 20% of the weight bearing. Therefore, when the anterior and middle columns are not satisfactorily supported because of vertebral hollowing, the posterior column bears 100% of the weight. As a result, the stress is concentrated in the posterior screw–rod system, resulting in long-term stress on the internal fixation and increasing the risk of post-traumatic delayed vertebral collapse, internal fixation failure, and nonunion. Therefore, it is important to prevent "shell" formation in the vertebral body.

Owing to difficulties in the preoperative detection of the vertebral "shell" intraoperative interventions are often difficult. The choice of surgical approach is currently advocated in favour of vertebral pedicle screw-based fixation combined with Percutaneous Vertebroplasty (PVP) or vertebral body bone grafting [1-3,5,6]. Hu et al. [3] have reported that intervention is required for patients with severe compression fractures (>50% compression) and osteoporosis. Depending on bone density, the use of short-segment screw–rod fixation combined with PVP or vertebral body bone grafting can minimize "shell" incidence, which is conducive to maintaining the height and long-term functional improvement of the injured vertebra, with satisfactory clinical outcomes. However, for patients with postoperative nonunion owing to the vertebral "shell" phenomenon, it is difficult for the bone cement to spread to the surrounding cancellous bone and fill the "shell" space because it is filled with fibrous tissues and sclerotic bone. Therefore, recollapse or refracture may occur after PVP, suggesting its ineffectiveness in patients with vertebral body "shell" [6]. Therefore, in patients with postoperative vertebral "shell"-induced nonunion, it is vital to remove the scar tissues and sclerotic bone from the vertebral "shell" before performing bone cement or bone graft filling.

The commonly used vertebral "shell" fillings in clinical settings include bone cement and autologous, allogeneic, and self-curing calcium phosphate artificial bones. Owing to its high osteogenic capacity and low immune response, autologous bone grafting remains the most widely used and effective method for bone defect repair and is considered the "gold standard" for bone grafting [7]. At present, grafting of the injured vertebral bone primarily involves intravertebral bone grafting via the narrow vertebral pedicle channels, increasing treatment difficulty and possibly leading to complications such as vertebral pedicle fracture and nerve root injury [8]. In contrast, bone grafting via superior pedicle notch approach is a relatively safer approach [9,10]. The superior pedicle notch is located below the intervertebral foramen and is a "safe zone" with no vascular nerves in the surroundings. Jiang et al. [10] have reported that the superior pedicle notch approach to PVP has a higher angle of abduction and sagittal view, therefore preventing neurovascular injury and decreasing radiation exposure and operation time. The superior pedicle notch is located in the upper one-third of the vertebral body and is adjacent to the "shell", providing an anatomical basis for the reconstruction of the injured spine. Bone grafting into the vertebral body via this channel can help fill the bone defect in the vertebral body and restabilize the anterior middle column of the vertebral body. Furthermore, preoperative imaging of the site and size of the vertebral body "shell" can help guide the reconstruction of the injured vertebra, increasing the precision of the bone grafting site and facilitating the use of an appropriate amount of bone graft [3]. Therefore, this approach combined with foraminoscopy-targeted bone grafting was used in the present study. Based on the literature review, for the first time, we used the superior pedicle notch approach to establish an operative channel as well as foraminoscopy-targeted bone graft filling under direct vision to treat the "shell". The larger operating space allowed for the complete removal of the L3 cavernous lesion. Furthermore, vascular nerve injury was prevented, considerably decreasing radiation and operation time. Moreover, the crucial structures of the posterior column of the vertebral body were not damaged and the stability of the internal fixation device remained unaffected. In addition, apart from avoiding the risk of vertebral pedicle rupture, this approach also provided a large bone graft access, allowing adequate bone grafting and filling of the vertebral "shell". In this case, regular postoperative follow-up examinations of the patient revealed notable relief from low back pain, and the lumbar 3 vertebral fracture healed bony and the internal fixation device was removed. Therefore, we hypothesize that this procedure has the advantages of being minimally invasive, precise, safe, and effective.

The reported treatment strategy for the vertebral "shell" can be summarized as follows: (1) the fracture should be preoperatively evaluated for the degree of compression, bone density, and disc integrity of the injured vertebra, and intraoperative interventions should aim to decrease the incidence of the "shell" [1,3]; (2) patients with normal bone density and mild compression may undergo posterior short-segment screw–rod fixation, whereas those with osteoporosis should undergo PVP or percutaneous kyphoplasty (PKP); (3) for severe compression fractures (≥50% compression) with (severe) osteoporosis, short- or long-segment fixation with bone cement and a vertebral pedicle screw is recommended; if spinal nerve injury is present, decompression should be performed based on magnetic resonance images; (4) for severe compression fractures (≥50% compression), in case of normal bone density, posterior short- or long-segment screw–rod fixation and reduction should be combined with intravertebral bone grafting and the injured vertebra or intervertebral fusion should be supported; if spinal nerve injury is present, intraoperative decompression should be performed as mentioned in (3); and (5) in cases where the vertebral "shell" not significantly reduced at 9 months postoperatively resulting in non-union of the fracture, targeted removal of the "shell" lesions under a spinal endoscopy using the superior pedicle notch approach should be performed promptly. Patients with normal bone density may undergo bone grafting, whereas patients with osteoporosis may receive row bone cement filling. With continuous improvements and advances in minimally invasive spinal devices and intervertebral foraminoscopic techniques, the treatment of patients with vertebral "shell"-induced nonunion can be rapidly developed and become an alternative strategy to PVP or PKP. Nevertheless, the present study has some limitations, including a small sample size and short follow-up time. In addition, the timing of postoperative bone grafting intervention should be investigated. Future studies will focus on addressing these limitations to provide a basis for the clinical treatment of such patients.

Conclusion

During the treatment of the postoperative "shell" phenomenon in vertebral fractures in the thoracolumbar spine, the fracture and condition of the patient should be thoroughly assessed preoperatively. Furthermore, immediate intraoperative interventions can help prevent serious complications of the postoperative "shell" phenomenon. Moreover, regular follow-up visits should be scheduled for such patients. For patients with vertebral nonunion caused by the "shell" phenomenon at 9 months postoperatively, spinal endoscopy-targeted bone grafting via the superior pedicle notch approach can be performed. This novel approach can effectively support the anterior vertebral column, promote fracture healing, and present the advantages of less trauma, faster recovery, and better efficacy. Therefore, we highly recommend spinal endoscopy-targeted bone grafting and filling via the subvertebral pedicle incisure approach for treating the postoperative "shell" phenomenon.

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