Original Article

A safe and reproducible anterior column restoration technique for Kümmell's disease: transpedicular bone packing

Chul Gie Hong^, Woo Dong Nam^, Jinwon Jang^

Department of Orthopedic Surgery, Kangwon National University Hospital, Chuncheon-si, Korea

Contributions: (I) Conception and design: CG Hong, WD Nam; (II) Administrative support: J Jang, WD Nam; (III) Provision of study materials or patients: CG Hong, J Jang; (IV) Collection and assembly of data: CG Hong, J Jang; (V) Data analysis and interpretation: CG Hong, J Jang; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Woo Dong Nam, MD, PhD. Department of Orthopedic Surgery, Kangwon National University Hospital, Baengnyeong-ro 156, Chuncheon-si, Gangwon-do 24289, Korea. Email: rokmc-hongie@daum.net.

Background: Kümmell's disease (KD), delayed post-traumatic vertebral collapse, is diagnosed with characteristic radiologic findings such as intravertebral vacuum cleft (IVC). Because patients with KD are elderly, have many underlying diseases, poor bone quality, and relatively limited surgical outcomes compared to other spinal diseases. The aim of this study is to describe a minimally invasive surgical technique and to evaluate the clinical and radiological outcomes of this technique.

Methods: As a surgical treatment method for KD, we performed bone substitute packing via small pedicle holes with a posterior instrumented fusion. Ten consecutive patients underwent surgery for KD. Clinical outcomes and radiologic parameters were evaluated pre- and post-operatively.

Results: The average operation time was 150.5±19.64 min with a mean estimated blood loss of 252±173.32 mL. The mean Visual Analog Scale (VAS) score for back pain was reduced from preoperative 8.7±0.82 to 2.8±1.14 (P<0.001), and the mean Oswestry Disability Index (ODI) score improved from 30.6±3.2 preoperatively to 11.6±4.81 (P<0.001) at the final follow-up. The sagittal Cobb angles decreased from 23.19±9.52 degrees preoperatively to 11.59±10.06 degrees (P<0.001) immediately after surgery, and 13.31±10.43 (P=0.002) degrees at the final follow-up. Except for 1 case of minor screw migration, there were no serious perioperative complications.

Conclusions: Transpedicular bone packing does not involve technically demanding procedures such as corrective osteotomy, vertebral column resection, and insertion of large metal cage. Therefore, it may be minimally invasive and reproducible surgical option.

Keywords: Minimal invasive spine surgery; osteoporotic spine fracture; transpedicular surgery; Kümmell's disease (KD)

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Introduction

Kümmell first reported delayed post-traumatic vertebral collapse following minor spine trauma in 1985 (1,2). Subsequently, the term Kümmell's disease (KD) has been used interchangeably with terms such as intravertebral pseudarthrosis, intravertebral vacuum cleft (IVC), vertebral body necrosis, and nonunion of compression fractures (3,4). Although rarely reported, the prevalence of KD is increasing with population aging. If various conservative treatments are ineffective, invasive treatment is required. The method of treatment is selected considering the severity or duration

^ ORCID: Chul Gie Hong, 0000-0003-0262-5269; Woo Dong Nam, 0000-0001-5117-2521; Jinwon Jang, 0009-0002-2052-8104.

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of back pain, presence of neurological symptoms, and degree of kyphotic deformity (5). It has been reported that back pain can be improved with cement augmentation, such as vertebroplasty or kyphoplasty; however, this method has been associated with complications in the long-term follow-up because cement does not promote bone healing (5,6). On the other hand, in patients with neurological deficits, severe kyphotic deformity, or progressive bone destruction, surgical treatment is required and cement augmentation is deemed inappropriate. Posterior instrumented fusion, with or without anterior corpectomy, is considered a conventional surgical procedure. Patients with KD are elderly and often have many underlying diseases; therefore, because anterior column surgeries, such as corpectomy, are technically demanding, the incidence of surgery-related complications is very high (7).

Considering the drawbacks with conventional methods, we considered minimally invasive surgical options for the treatment of KD. We performed bone substitute packing through the bilateral pedicles for anterior column restoration and promoted intravertebral bone healing using a conventional posterior fusion technique. This study aimed to describe transpedicular bone substitute packing for KD and to evaluate the clinical and radiological outcomes of this technique. We present this article in accordance with the AME Case Series reporting checklist (available at https://jss.amegroups.com/article/view/10.21037/jss-24-121/rc).

Highlight box

Key findings

- Because patients with Kümmell's disease are relatively elderly, have many underlying diseases, poor bone quality, and have limited surgical outcomes, efforts should be made to reduce surgery-related complications.

What is known and what is new?

- Transpedicular approach, a relatively minimal invasive spine surgery that allows access to the vertebral body has been introduced.
- Transpedicular bone substitute packing can sufficiently restore a collapsed vertebral body and provide stable mechanical support to anterior column without a bone harvesting procedure.

What is the implication, and what should change now?

- Transpedicular bone packing is safe and reproducible surgical option.

Methods

Study design

This retrospective study was performed to evaluate a new surgical technique for the treatment of KD. Between August 2019 and January 2022, 10 consecutive patients underwent surgery for KD at our hospital using transpedicular bone packing with long-segment instrumented fusion. All the surgeries were performed by a single surgeon (C.G.H.). The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by institutional committee board of Kangwon National University Hospital Institutional Review Board (S-880/2021). The requirement for informed consent was waived because of its retrospective nature.

Diagnosis of KD

KD was diagnosed using a combination of simple radiography, computed tomography (CT), and magnetic resonance imaging (MRI) (3,4,8). Verification of intervertebral motion observed in dynamic flexion and extension lateral radiography aided in the diagnosis (*Figure 1*) (9). As is standard for the treatment of spinal diseases, conservative treatment, including immobilization and a pain management program, was considered first (10). The indications for surgery were as follows: neurological deterioration, prolonged pain refractory to non-surgical management, and progressive bony deformity such as segmental kyphotic change.

Patient characteristics

The patients' demographic data and baseline characteristics were collected from electronic chart reviews, including bone mineral density (BMD), symptom duration, neurological presentation, and medical comorbidities (*Table 1*). Clinical parameters were evaluated pre- and postoperatively, which included Visual Analog Scale (VAS) scores for back and leg pain, and the Oswestry Disability Index (ODI) score (*Table 2*) (11). Data on the operative time, estimated blood loss, and perioperative complications were also collected (*Table 1*). The height of the injured vertebra was measured as the distance between the upper and lower endplates of the anterior column in standing lateral radiography. When standing was not possible due to excruciating pain,

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Figure 1 The intravertebral vacuum cleft sign (asterisk) was confirmed on the 12th thoracic vertebra on computed tomography (A,B) and lateral X-ray (C,D) taken 3 months after the injury. Confirming intravertebral motion observed in dynamic flexion (C) and extension lateral radiography (D) can be helpful in diagnosing Kümmell's disease.

Table 1 Clinical and surgical data of patients

Case	Sex/age (years)	Level of injury	Level of fixation	Duration of symptom (months)	Injury mechanism	Underlying disease	Symptom	BMD	Op time (min)	EBL (cc)
1	F/70	T12	T10–L1	3	Fall from height	COPD, DM	Intractable back pain, progressive kyphotic deformity	–2.7	140	200
2	F/81	T11	T9–L1	2	No memory of an injury event	DM, chemotherapy for cholangiocarcinoma	Back pain with lower extremity muscle weakness	–3.0	130	100
3	M/81	T12	T10–L2	4	Fall from height	HTN, DM	Back pain and flank pain	–0.6	140	300
4	F/83	L1	T11–L3	3	Fall from height	HTN, DM, cerebral infarction	Intractable back pain, progressive kyphotic deformity	–2.1	175	400
5	F/78	T12	T10–L2	3	Fall from height	DM	Intractable back pain	–3.0	170	20
6	F/79	L1	T11–L3	1	Fall from height	Coronary artery disease, dementia, hyperlipidemia	Back pain with lower extremity muscle weakness	–2.6	140	200
7	F/80	T12	T10–L2	2	Fall from height	HTN, DM, coronary artery disease	Lower back pain with radiating pain to both leg, progressive kyphotic deformity	–2.3	185	500
8	F/85	L1	T12–L2	1.5	Fall from height	HTN, asthma	Back pain with lower extremity muscle weakness	–3.0	130	500
9	F/81	L2	T12–L4	1.5	No memory of an injury event	DM, HTN, cerebral infarction	Back pain with lower extremity muscle weakness, progressive kyphotic deformity	–2.5	155	250
10	F/87	T12	T10–L2	3	Fall from height	HTN, hyperlipidemia	Lower back pain with radiating pain to both leg	–3.4	140	50

BMD, bone mineral density; Op time, operating time; EBL, estimated blood loss; F, female; M, male; COPD, chronic obstructive lung disease; DM, diabetes mellitus; HTN, hypertension.

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Table 2 Surgical and radiological outcomes

Case	VAS score*		ODI score*		Cobb's angle (°)*			Vertebral height (mm)*		
	Pre-op	Final f/u	Pre-op	Final f/u	Pre-op	Post-op (Imm.)	Final f/u	Pre-op	Post-op (Imm.)	Final f/u
1	9	2	30	11	23.77	15.43	19.05	12.75	21.66	18.21
2	10	3	34	14	33.10	26.94	30.30	13.13	15.35	14.31
3	7	1	32	10	24.59	21.04	24.98	21.73	23.02	19.87
4	9	4	36	5	21.97	9.01	11.34	14.30	24.81	24.17
5	9	5	29	4	15.38	0.94	1.04	12.50	24.76	23.87
6	9	2	28	14	9.14	0.68	1.43	20.70	29.89	29.54
7	8	3	27	12	27.97	13.23	13.98	1.71	16.97	15.96
8	8	3	26	10	12.90	3.18	8.62	11.37	19.93	17.06
9	9	3	31	16	21.90	1.38	1.33	15.20	26.46	26.11
10	9	2	33	20	41.20	24.04	21.04	2.20	21.14	20.50

*, P<0.001. VAS, Visual Analog Scale; ODI, Oswestry Disability Index; Pre-op, preoperative; Post-op, postoperative; Post-op (Imm.), immediate postoperative; f/u, follow-up.

radiography images were obtained in the supine position. Regional sagittal angles were estimated using Cobb's method, which consists of the upper endplate of the upper vertebra and the lower endplate of the lower vertebra adjacent to the injured vertebral body.

Surgical procedures

Patients were placed in the prone position under general anesthesia. Pedicle screws were inserted on the two segments above and below the injured vertebral body, and cement-augmented cannulated pedicle screws were used in cases with poor bone quality. To create pedicle holes to access the inside of the collapsed vertebral body, we inserted and removed a large diameter (7.5–8.0 mm) pedicle screw. Dilators were used to widen the pedicle hole to accommodate the bone impactor. Necrotic tissues inside the vertebral body were removed through the pedicle holes using pituitary forceps. A hydroxyapatite bone substitute (BONGROS, CG Bio, Gyeonggi, Korea) with a volume of approximately 30 cc was inserted into the vertebral body as much as possible via the pedicle holes on both sides. The bone substitutes were filled by repeatedly applying pressure to a cylindrical bone impactor until sufficient resistance was experienced (*Figure 2*). At this point, the vertebral height was restored without a separate reduction procedure because of the internal pressure generated as the bone substitute was loaded into the vertebral body. Because the anterior longitudinal ligament blocks the front of the vertebral body, even if the bone substitutes are pushed in with sufficient pressure, they do not leak out of the vertebral body. After connecting the rods, local bony fragments derived from decoration or decompression procedures were grafted posteriorly to the lamina. One week postoperatively, ambulatory activities while wearing a brace were encouraged. The brace was worn for 12 weeks.

Statistical analysis

Statistical analyses were performed using Wilcoxon signed-rank tests and paired *t*-tests (SPSS 17.0, SPSS Inc., IBM Corp., Armonk, NY, USA). Statistical significance was set at P<0.05.

Results

In total, one male and nine females were included in this study, with an average age of 80.5±4.58 years (range, 70–87 years). The risk of surgery was predicted to be extremely high because all patients had various underlying diseases (*Table 1*). All patients were followed up for >12 months, with an average follow-up period of 26.6±4.2 months. The level of injury was T11 in one patient, T12 in five, L1 in three, and L2 in one. All vertebral bodies were damaged at the thoracolumbar junction (T11–L2), with T12 and L1 being the most common (80%). The average duration

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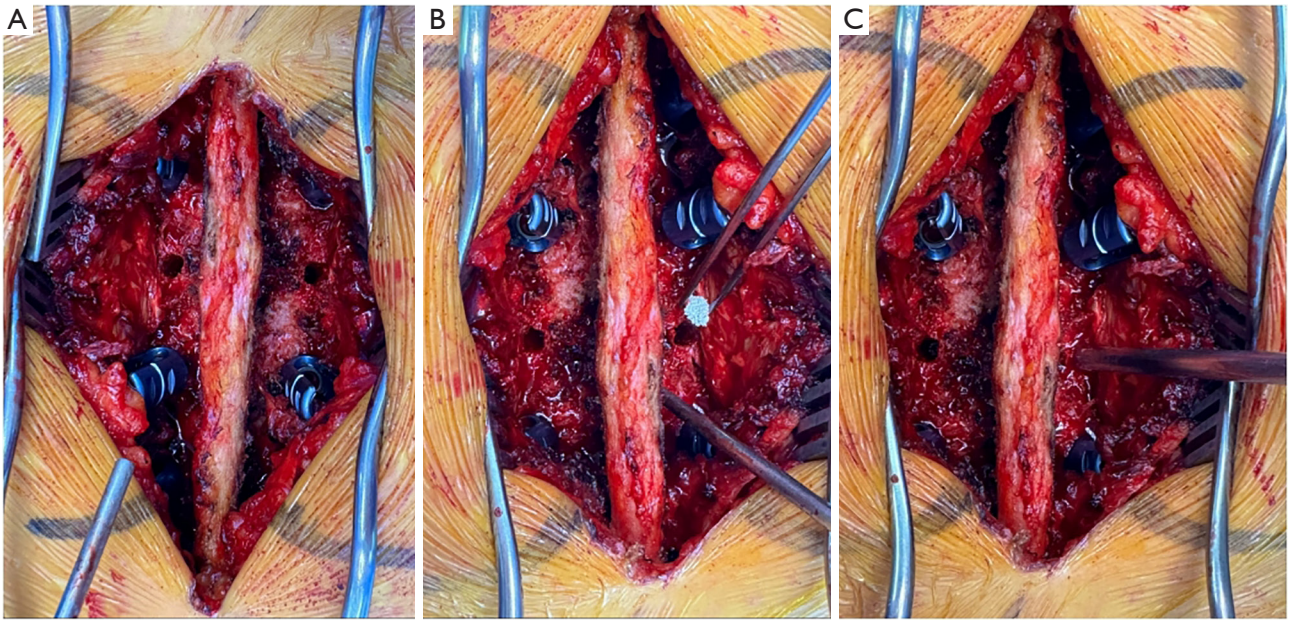

Figure 2 Intraoperative photos. Pedicle holes were created on both sides leading to the inside of the vertebral body (A). Hydroxyapatite bone substitutes were inserted into the vertebral body as much as possible via the pedicle holes (B). Using a bone impactor, the bone substitutes were filled into the vertebral body with sufficient pressure (C).

of symptoms was 2.4±0.94 months (range, 1–4 months). Key symptoms leading to the decision to undergo surgery during conservative treatment included refractory back and flank pain, progressive kyphotic deformity, and lower extremity pain with muscle weakness (7). Among the 10 patients, eight had a history of mild injuries, such as falls from a height, and two patients had no clear memory of an accident. The average BMD was –2.52±0.78 (range, –3.4 to –0.6), and seven of the 10 patients had osteoporosis, with a BMD of –2.5 or less.

The average operation time was 150.5±19.64 min (range, 130–185 min) with a mean estimated blood loss of 252±173.32 mL (range, 20–500 mL). No surgery-related complications, such as dural tears with transient cerebrospinal fluid leakage or neurological deterioration, occurred in this study. Most patients complained of severe pain before surgery and experienced limitations in their daily activities; therefore, pain was evaluated using high ODI and VAS scores. The mean VAS score for back pain was reduced from preoperative 8.7±0.82 to 2.8±1.14 (P<0.001), and the mean ODI score improved from 30.6±3.2 preoperatively to 11.6±4.81 (P<0.001) at the final follow-up. The sagittal Cobb angles decreased from 23.19±9.52 degrees preoperatively to 11.59±10.06 degrees (P<0.001) immediately after surgery, and 13.31±10.43 (P=0.002) degrees at the final follow-up (*Table 2*). The segmental kyphotic deformity that recovered after surgery slightly increased during the follow-up period and eventually stabilized. The vertebral height recovered from 12.56±6.56 mm preoperatively to 22.40±4.37 mm (P<0.001) immediately after surgery, and 20.96±4.86 mm (P=0.002) degrees at the final follow-up (*Table 2*). The height of the collapsed vertebral body restored after surgery slightly decreased during the follow-up period and eventually stabilized.

There were no cases of serious implant-related complications such as screw pull-out or rod breakage. In one case, despite the use of cemented screws, angulation of the pedicle screws on the lower instrumented vertebra was observed; however, there was no endplate violation or interval change on follow-up imaging; therefore, no additional surgery was performed.

Discussion

As the number of patients with osteoporotic fractures gradually increases with the aging population, the incidence of KD is also increasing (2,9,12). As is standard for spinal diseases, the primary treatment option is conservative management. Nonsurgical treatment for KD includes bed

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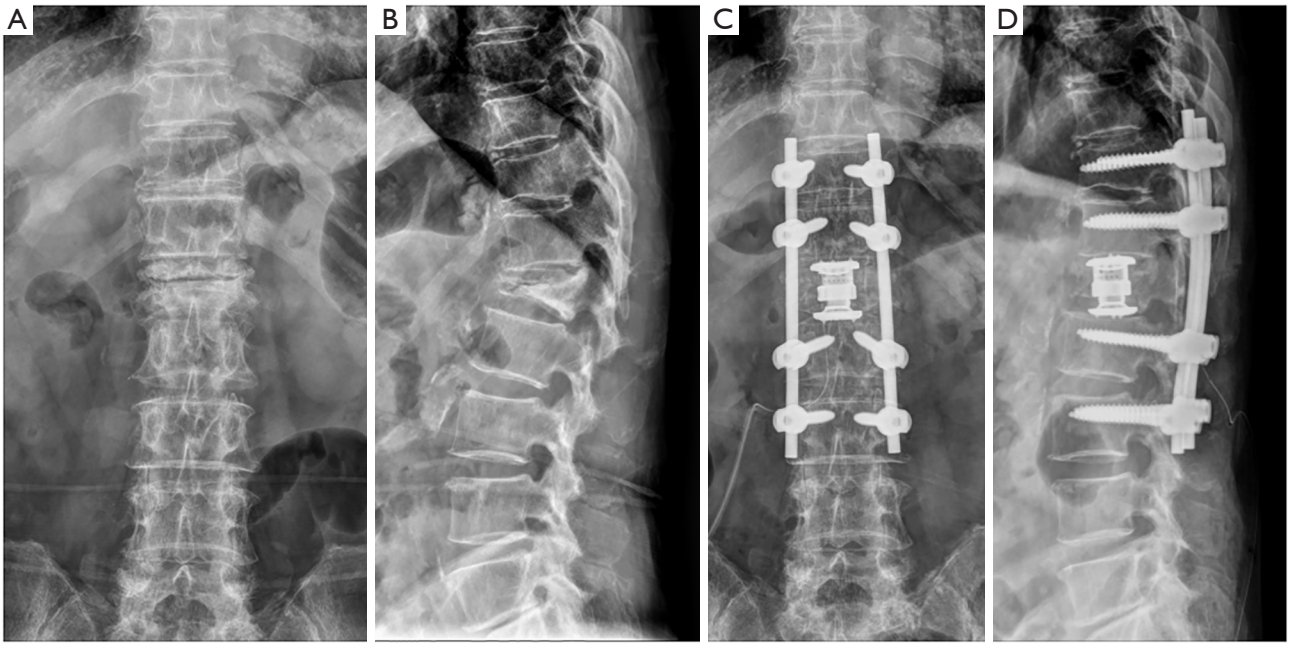

Figure 3 Conventional corpectomy case. A 73-year-old female patient was diagnosed with L1 Kümmell's disease and underwent surgery after 3 months of conservative treatment. Since the bone quality was relatively not poor, corpectomy following metal cage insertion and posterior instrumentation with fusion was performed via a posterior only approach. However, this required relatively long operating time (operating time =210 min) and large amount of blood loss (estimated blood loss =900 cc). (A) Preoperative anteroposterior X-ray demonstrates intravertebral vacuum cleft on the 1st lumbar vertebra. (B) Preoperative lateral X-ray shows L1 vertebral body collapse with segmental kyphosis. (C) Postoperative anteroposterior X-ray. After removing the whole vertebral body of L1 through a posterior approach, anterior support was performed using expandable cage. (D) Postoperative lateral X-ray shows improvement of segmental alignment.

rest, wearing a brace, analgesics, and anti-osteoporosis medications; however, satisfactory results are not always achieved (4,7,13,14).

If pain persists and does not respond to noninvasive treatment, cement augmentation may be considered. Cement augmentation is a widely used treatment option for osteoporotic vertebral compression fractures; however, the role of cement augmentation for KD remains controversial (13,14). Although cement augmentation is anticipated to immediately reduce back pain, many surgeons believe that it actually negatively impacts bone healing, causing long-term complications such as dislodgement of injected cement or adjacent vertebral body fracture (15). Additionally, if the continuity of the posterior cortical bone of the vertebral body is broken, there is a risk of cement leakage into the epidural space; therefore, caution is required (16,17). As a result, we do not favor cement augmentation as a treatment for KD.

Surgical treatment of KD should always be considered as the final treatment option. This is because patients with KD tend to be older, have a high number of underlying medical conditions, and have poor bone quality; therefore, surgical complications are expected to be common and potentially fatal (18,19). The goal of surgery in the treatment of KD is to decompress the spinal cord, restore physiological spinal alignment, and maintain spinal stability. Anterior column surgery, such as corpectomy via the anterior or posterior approach, can be an effective method to restore the physiological alignment and provide stability of the anterior spinal column (*Figure 3*) (7,14,20). However, because corpectomy is technically demanding and usually involves a longer operative time and a relatively large amount of blood loss, there is a high possibility of various perioperative complications (pneumonia, internal organ injury, and intensive care unit admission). Furthermore, inserting a large metal cage into an osteoporotic spine carries the risk of cage subsidence and migration (21,22).

Various graft materials can be used to fill the intravertebral cleft, such as autologous bone grafts, allografts, demineralized bone matrices, or other bone

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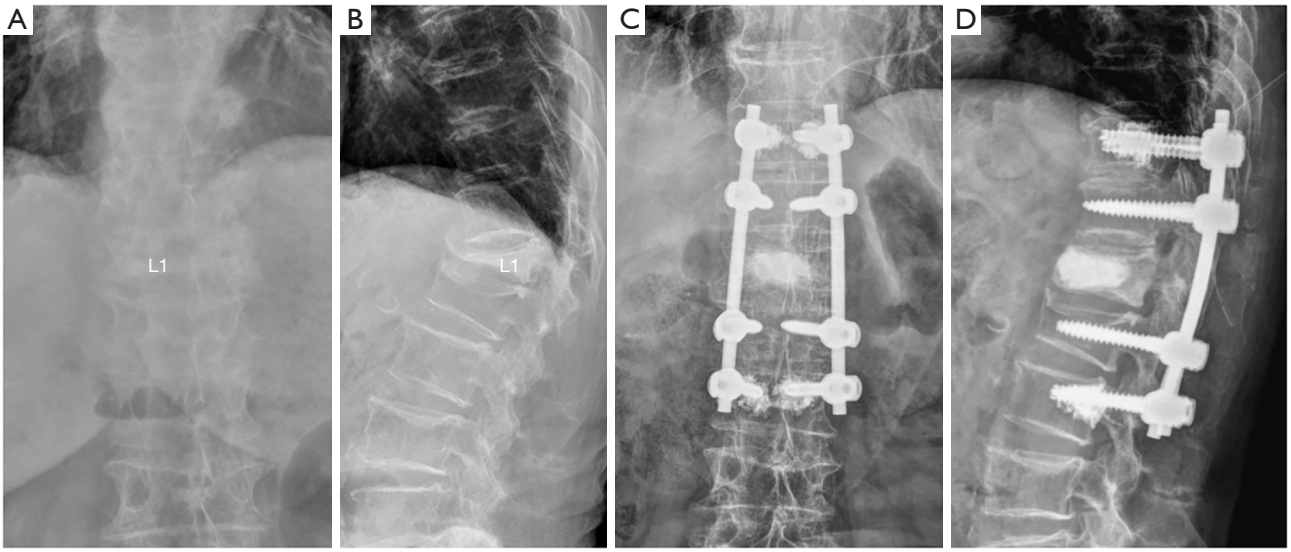

Figure 4 Illustrative case 1. An 83-year-old female patient came to the hospital with severe back pain and kyphosis that had persisted for several months. She did not suffer from any neurologic symptom. On X-ray, segmental kyphosis was observed with the apex of L1 vertebra (A,B). After transpedicular bone packing using bone substitute, posterior long segment fusion was performed (C,D).

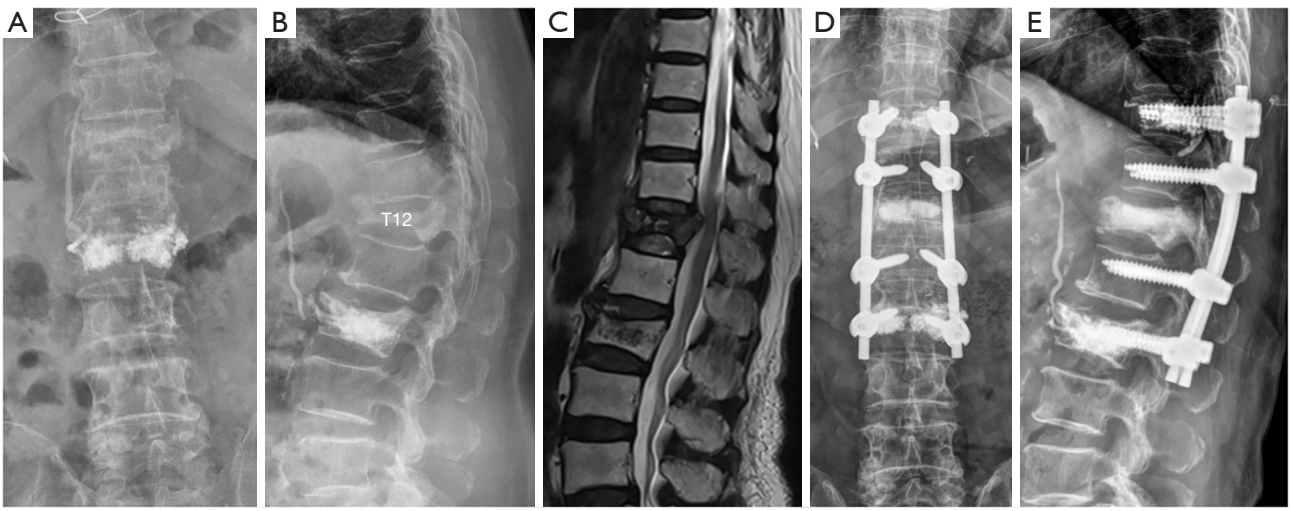

Figure 5 Illustrative case 2. An 87-year-old female patient came to the hospital with complaints of back and both leg pain for 2 weeks. X-ray shows compression fracture and suspicious Kümmell's disease at T12 (A,B). On magnetic resonance imaging, spinal cord was compressed by the posteriorly bulged bone fragment (C). After transpedicular bone packing using bone substitute, posterior fusion was performed (D,E). The proximal screw was reinforced with cemented screws (E).

substitutes. Autologous bone graft from the iliac bone is the most effective graft material as it offers osteogenic, osteoinductive, and osteoconductive capabilities, all while avoiding immune system rejection (23). Nevertheless, harvesting autografts also has some risks due to the additional surgery, such as prolonged operation time, increased blood loss, and pain at the donor site (23). In our study, approximately 20–30 cc of hydroxyapatite bone substitutes were needed to restore and support the collapsed vertebral body by filling it into the vertebral body (*Figures 4-6*); however, obtaining this amount of bone from a single harvest site would be difficult.

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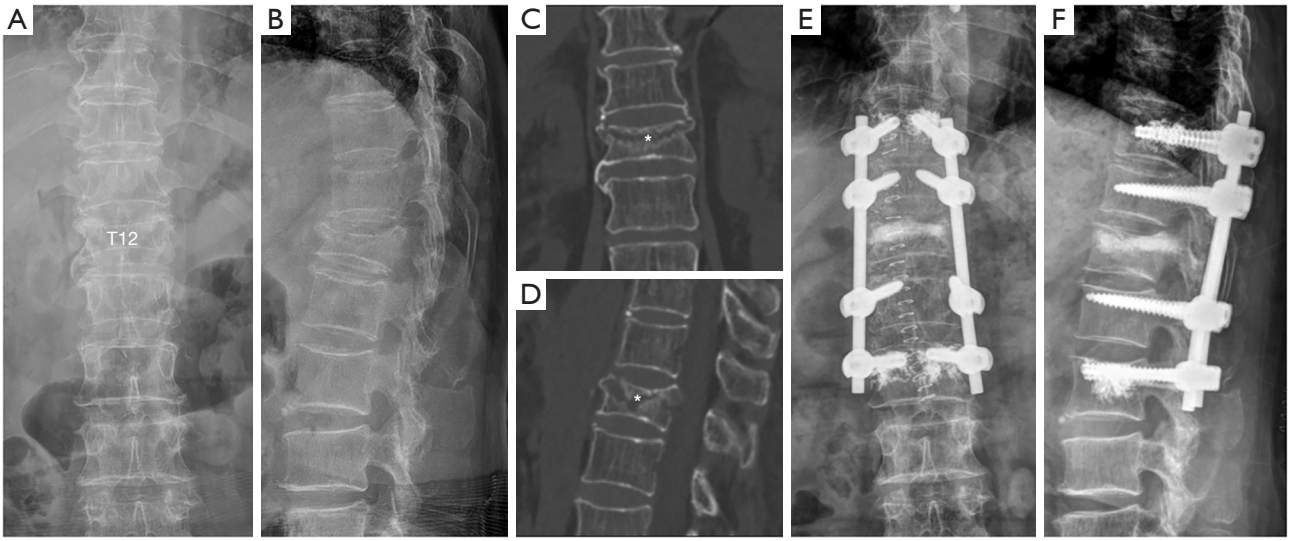

Figure 6 Illustrative case 3. An 81-year-old male patient came to the hospital with severe back pain and flank pain that had persisted for several years. The intravertebral vacuum cleft sign (asterisk) was confirmed on the 12th thoracic vertebra on X-ray (A,B) and computed tomography (C,D). Postoperative images (E,F) show recovery of vertebral height.

Because KD usually occurs secondary to osteoporosis, implant failure frequently occurs in patients who have undergone short-segment fixation (24). Thus, we used long-segment fixation to stabilize the spine. In thoracolumbar spine surgery for patients with osteoporosis, screw loosening, migration, and pullout occur frequently, and several pedicle screw fixation methods have been developed to improve pullout strength while reducing implant-related complications (24). These methods include increasing the diameter and/or length of the pedicle screw, reinforcement with a laminar hook, and screw insertion with cement. Among these methods, cement-augmented cannulated pedicle screws are the most widely used. Choi *et al.* compared the rate of implant failure according to the use of solid pedicle screws or cement-augmented cannulated pedicle screws in lumbar fusion surgery (25). The cement-augmented cannulated pedicle screw group (5.1%, 3/59) showed a statistically lower rate of implant failure than the solid pedicle screw group (15.3%, 18/118). In our study, cement-augmented cannulated pedicle screws were inserted only in the upper and lower instrumented vertebrae. No serious screw-related complications occurred during the follow-up period (*Figures 4-6*).

A limitation of this study is that the number of cases was relatively small, which may not have been sufficient to account for the long-term clinical and radiological outcomes. However, during the follow-up period, the results from our series show that this surgical method resulted in satisfactory symptomatic and radiologic improvement with a lower incidence of perioperative complications and mortality or morbidity.

Conclusions

In summary, as patients with KD are relatively elderly, have many underlying diseases, poor bone quality, and have limited surgical outcomes compared with patients with other spinal diseases, efforts should be made to reduce surgery-related complications. Transpedicular bone packing does not involve technically demanding procedures, such as corrective osteotomy, vertebral column resection, and large metal cage insertion. Therefore, this approach is minimally invasive and reproducible. Furthermore, bone substitute packing creates sufficient intravertebral pressure, which can be expected to not only restore the shape of the collapsed vertebral body but also promote intravertebral bone healing.

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Footnote

Reporting Checklist: The authors have completed the AME Case Series reporting checklist. Available at https://jss.amegroups.com/article/view/10.21037/jss-24-121/rc

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by institutional committee board of Kangwon National University Hospital Institutional Review Board (S-880/2021). The requirement for informed consent was waived because of its retrospective nature.

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