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Kyphoplasty with Posterior Dynamic Stabilization in the Surgical Treatment of Unstable Thoracolumbar Osteoporotic Vertebral Compression Fractures

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ABSTRACT

AIM: To evaluate the role of posterior dynamic stabilization (PDS) with kyphoplasty (KP) in the surgical treatment of unstable osteoporotic compression fractures, which are common in the elderly population.

MATERIAL and METHODS: This study included 25 patients with osteoporotic compression fractures. KP with PDS was performed on all patients. Radiological evaluation was performed with magnetic resonance imaging, computed tomography, and plain radiographs. The vertebral kyphosis angle (VKA), local kyphosis angle (LKA), and percentage of collapse were calculated. Clinical evaluation was performed with the visual analog scale and the Oswestry Disability Index (ODI). The preoperative and postoperative clinical and radiological data were compared.

RESULTS: The clinical and radiological parameters showed significant improvement following surgical treatment. The mean preoperative visual analog scale score of 7.78 decreased to 0.94 after 12 months. The mean preoperative ODI score of 70.33 decreased to 15.65 after 12 months. The mean preoperative VKA of 17.89° decreased to 9.22° after 12 months. The mean preoperative LKA of 9.61° decreased to 5.50° after 12 months. The mean preoperative percentage of collapse of 32.56% decreased to 19.00% after 12 months. There were no major complications.

CONCLUSION: KP with the PDS method offered satisfactory outcomes in the surgical treatment of unstable osteoporotic compression fractures.

KEYWORDS: Kyphoplasty, Posterior dynamic stabilization, Osteoporotic compression fractures

INTRODUCTION

Osteoporosis is a systemic skeletal disease characterized by low bone mass with micro-architectural alterations that increase bone fragility. Vertebral compression fracture (VCF) is the most common complication of osteoporosis, and the risk of VCF increases with age (12). Osteoporotic VCF usually causes severe, persistent back pain that limits normal activities of daily life and thus decreases the quality of life (14). Traditional conservative treatment is based on bed rest, spine immobilization with a brace, medical pain management, and physical therapy. Although many patients achieve satisfactory outcomes with conservative treatment, conservative treatment fails in a large portion of patients. Particularly, patients with kyphotic deformities or those who develop kyphosis during conservative treatment may remain in a painful, debilitating condition requiring surgical treatment (10). Percutaneous vertebroplasty and kyphoplasty (KP) are minimally invasive techniques in the surgical

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treatment of osteoporotic VCF (16). Both techniques involve cement augmentation of the fractured vertebral corpus. In vertebroplasty, polymethylmethacrylate (PMMA) is injected into the vertebral corpus to stabilize the fracture. In KP, first, a balloon is inflated inside the vertebral corpus to raise the vertebral body height, and then PMMA is injected. Both methods offer rapid pain control and improve function better than conservative treatment (19). However, there might be a risk of fracture progression after cement augmentation and the persistence of instability following KP (19). In recent years, a new method has been described to eliminate the risk of fracture progression and new fractures at adjacent segments following the cement application. The hybrid stabilization method comprising KP of the fractured vertebral corpus with posterior cement-augmented stabilization offered satisfactory outcomes in patients with higher fracture instability (15).

For the surgical treatment of degenerative spinal disorders, the posterior dynamic stabilization (PDS) technique has increased in popularity in the last two decades. The PDS technique effectively stabilizes the unstable spinal segments as rigid systems (3). The study presented here evaluates the role of PDS in the surgical treatment of osteoporotic VCF with KP.

MATERIAL and METHODS

This retrospective study evaluated patients with osteoporotic thoracolumbar compression fractures who underwent surgery between 2006 and 2014 with balloon KP and PDS. In total, 25 patients (16 females and 9 males; mean age: 72.4 years) were included in this study. The Dennis classification method was applied to classify the fracture types (2). All patients were considered to have either type A or B fractures. Significant vertebral height loss (min. 40%) and/or kyphotic deformity were considered unstable fractures. Afterward, the "Arbeitsgemeinschaft für Osteosynthesefragen" and "Osteoporotic Fracture" classification methods were applied to classify the fracture types (Table I) (13,17). All patients were considered to exhibit unstable fractures as per the "Osteoporotic Fracture" classification (13). Three patients exhibited multilevel osteoporotic VCF (Table I).

Clinical evaluations of the patients before surgery and 3 and 12 months after surgery were performed with the visual analog scale and the Oswestry Disability Index (ODI). The radiological assessments before surgery were performed using magnetic resonance imaging (25/25 patients), computed tomography (10/25 patients), and plain radiographs (25/25 patients). Plain

Table I: Patients Demographic Findings, Fracture Types and Levels

Patient No	Age	Gender	Level	AO Fracture Type	OF
1	86	M	L4	A2.3	4
2	89	M	T12	A3.3	5
3	67	M	T12-L1	A2.3 and A1.3	4-3
4	87	F	L3	A1.2	5
5	60	F	T12	A2.2	4
6	62	F	T11	A1.2	4
7	66	F	L1	A2.2	4
8	82	M	L2	A3.2	4
9	75	F	L4	A3.1	4
10	84	M	L1	A1.3	5
11	86	F	T12	A1.2	4
12	65	F	L1	A1.2	5
13	64	F	L4	A2.2	4
14	62	F	T12	A2.2	4
15	60	M	L4	A1.3	4
16	69	F	L4	A1.3	4
17	63	M	L2 and L4	A1.3 and A2.2	4-4
18	62	F	L1	A1.3	5
19	86	F	L1	A3.1	4
20	82	F	L1	A1.2	4
21	50	F	T3	A1.3	4
22	70	F	L5	A1.3	4
23	77	F	T9	A1.3	4
24	67	M	T12-L3	A1.1 and A2.3	4-4
25	81	M	L1	A1.3	3

***M:** Male, **F:** Female, **AO:** Arbeitsgemeinschaft für Osteosynthesefragen, **OF:** Osteoporotic fracture.*

radiographs were obtained from all patients immediately after surgery and 3 and 12 months after surgery. All patients underwent computed tomography examinations 12 months after surgery to evaluate screw loosening and/or fracture. Upon a new onset of significant pain after surgery, magnetic resonance imaging was performed (9/25). Radiological evaluations were based on three parameters that were obtained before surgery, immediately after surgery, and 3 and 12 months after surgery: a) vertebral kyphosis angle (VKA), b) local kyphosis angle (LKA), and c) the percentage of collapse (Figure 1) (20).

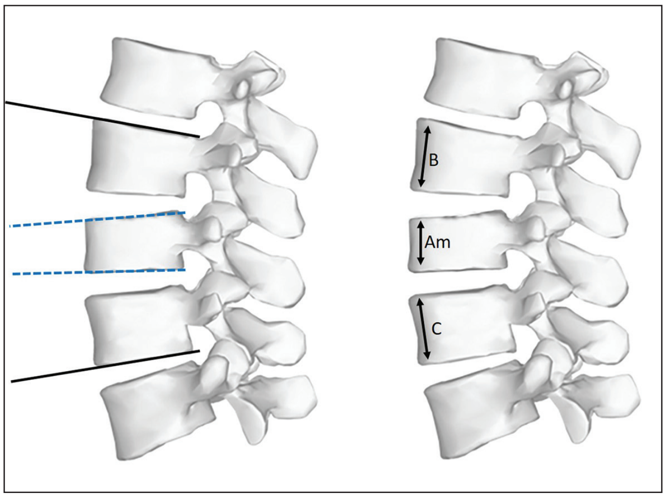

Figure 1: Measurements of the vertebral kyphosis angle (dashed lines) and the local kyphosis angle (solid lines). Percentage of collapse: **At:** (B + C) / 2. **Percentage of collapse=** (At – Am) / At).

Surgery

All patients were operated on under general anesthesia. KP was performed on a compressed vertebra. PDS (hinged screw–rigid rod) was performed on one level above and one level below the fractured vertebra. C-arm fluoroscopy and neuro-monitorization were used during KP and PDS. KP was performed with the bilateral approach. Following sufficient PMMA (Kyphon, HV-R, Medtronic, MN, USA) injection, transpedicular screws were placed through 1–2 cm skin incisions, and the rods were placed under the fascia and fixed to the screws (Safinaz, Medikon, Turkey) through the same skin incisions (Figure 2).

The statistical comparison of the preoperative and postoperative data was performed using the Number Cruncher Statistical System 2007 program (Kaysville, UT, USA). Additional tests were applied for the follow-up variables that did not show normal distribution (Friedman test) during paired comparison (Bonferroni Dunn test). Statistical significance was indicated with $p<0.05$.

All patients consulted with the endocrine department, and the appropriate osteoporosis treatment regimen was started immediately.

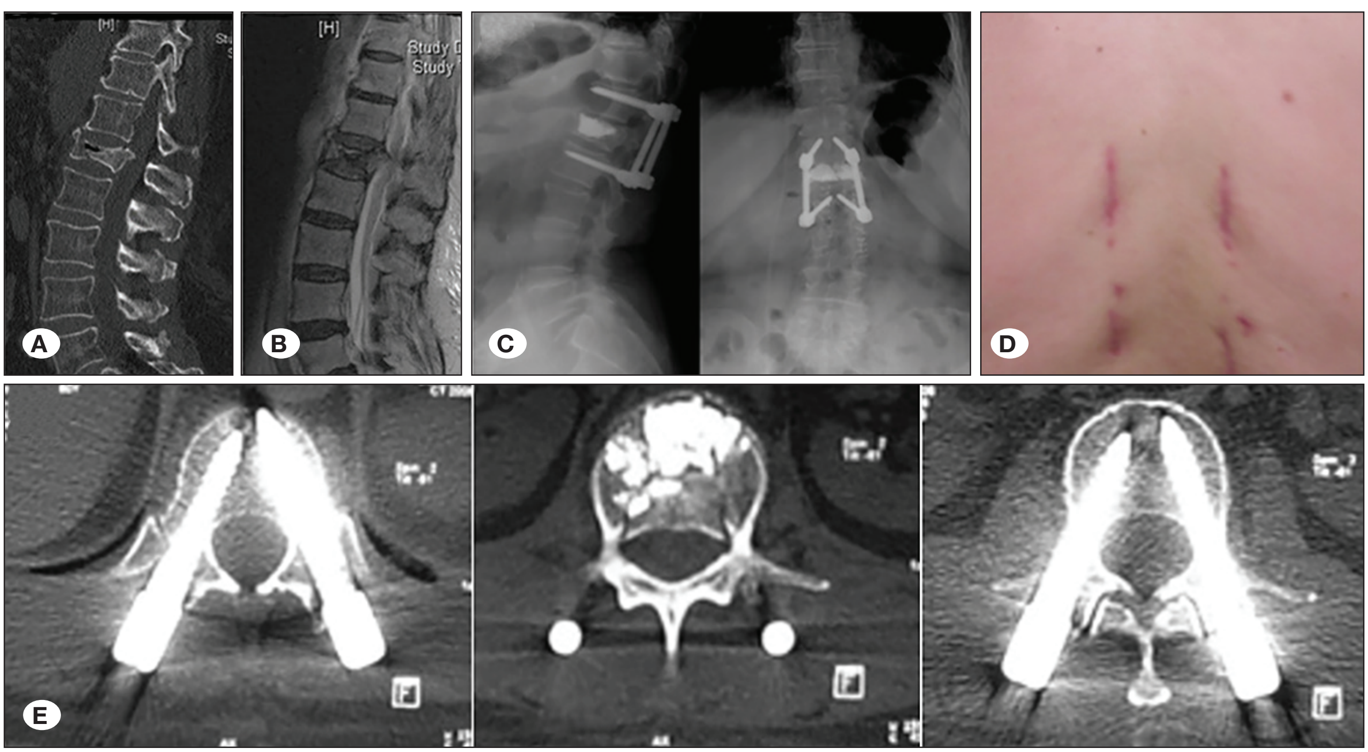

Figure 2: An 86-year-old female patient showed an osteoporotic L1 fracture. **A)** Sagittal computed tomography scan. **B)** Sagittal T2-weighted magnetic resonance imaging. **C)** Kyphoplasty with dynamic stabilization was performed. **D)** Minimally invasive surgery. **E)** Computed tomography revealed no screw complications during the first postoperative year.

RESULTS

The clinical and radiological parameters improved after surgery. The preoperative mean visual analog scale score was 7.78 and significantly decreased to 2.22 after 3 months and 0.94 after 12 months (Table II, Figure 3). Similar improvements were observed with the ODI scores. The preoperative mean ODI score was 70.33, and the postoperative scores significantly decreased to 29.67 and 15.65 after 3 and 12 months, respectively (Table II).

The radiological parameters also showed significant improvements after surgery. The preoperative mean percentage of collapse was 32.56%. These values decreased to 17.72%, 17.17%, and 19.00% immediately after surgery and after 3 and 12 months, respectively. The LKA data showed significant improvements after surgery. The preoperative mean LKA was 9.61° and significantly decreased to 6.33°, 5.28°, and 5.50° immediately after surgery and after 3 and 12 months, respectively. The VKA data showed significant corrections after surgery. The mean preoperative VKA was 17.89° and significantly

Table II: VAS and ODI Evaluation

		Min-Max (Median)	Mean±Sd
VAS	Preop	6 - 9 (8)	7.78 ± 0.88
	Postop 3rd month	1 - 3 (2)	2.22 ± 0.55
	Postop 12th month	0 - 2 (1)	0.94 ± 0.73
	p	**[a]0.001****	
	Preop - Postop 3rd month		**[b]0.002****
	Preop - Postop 12th month		**[b]0.001****
	Postop 3. month - 12th month		**[b]0.091**
ODI	Preop	54 - 86 (72)	70.33 ± 8.87
	Postop 3rd month	12 - 48 (30)	29.67 ± 10.70
	Postop 12th month	10 - 26 (16)	15.65 ± 4.76
	p	**[a]0.001****	
	Preop - Postop 3rd month		**[b]0.005****
	Preop - Postop 12th month		**[b]0.001****
	Postop 3. month - 12th month		**[b]0.049***

*[a]Kruskal Wallis Test, [b]Bonferroni Dunn Test, *p<0.05, **p<0.01.*

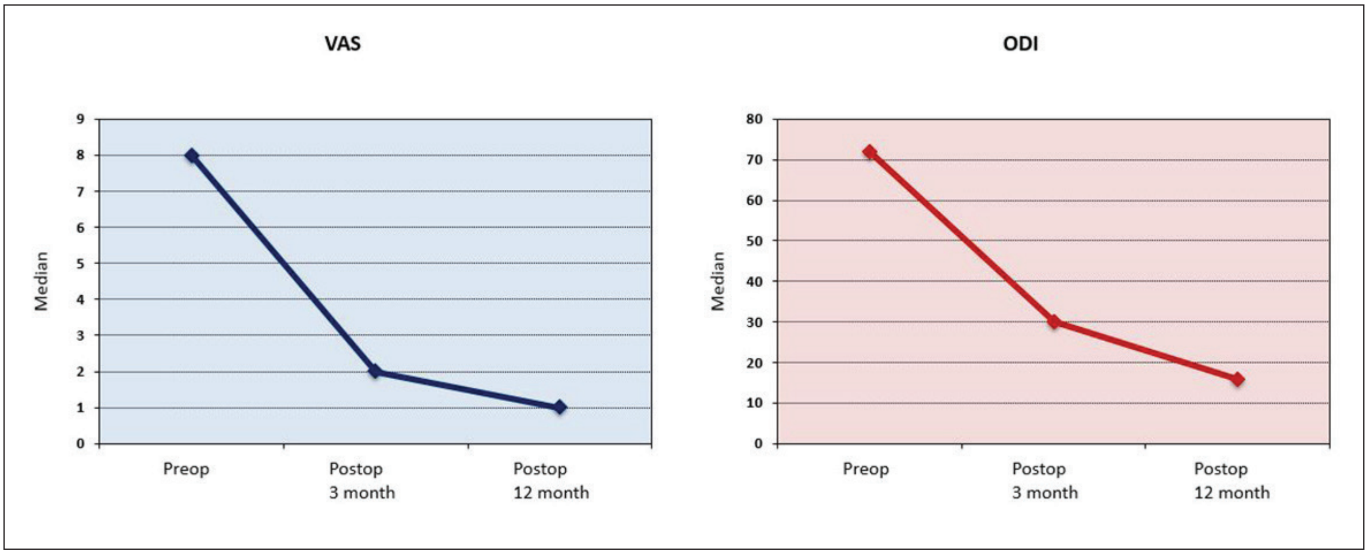

Figure 3: The distribution of the visual analog scale and the Oswestry Disability Index measurements during follow-up.

decreased to 8.00°, 8.56°, and 9.22° immediately after surgery and after 3 and 12 months, respectively (Table III, Figure 4).

One patient showed superficial wound infection and was treated with antibiotics and daily wound care. Three patients developed new compression fractures at adjacent levels postoperatively and were treated with conservative methods. Two patients developed superficial wound infections and were treated with the appropriate antibiotics. No complications related to bone cement application or metallic instruments (e.g., screw malposition, loosening, or breakage) were observed.

Table III: Radiologic Parameters, Preoperative, Early Postoperative and After 1 Year

		Min-Max (Median)	Mean ± SD
Vertebral kyphosis angle (VKA)	Preoperative	8 - 36 (16.5)	17.89 ± 7.53
	Postoperative	1 - 20 (7)	8.00 ± 5.12
	Postoperative 3rd month	2 - 20 (8.5)	8.56 ± 4.64
	Postoperative 12th month	2 - 22 (9)	9.22 ± 4.82
	p	**[a]0.001****	
	Preoperative - Postoperative		**[b]0.001****
	Preoperative - Postoperative 3rd month		**[b]0.001****
	Preoperative - Postoperative 12th month		**[b]0.009****
	Postoperative - Postoperative 3rd month		[b]0.639
	Postoperative - Postoperative 12th month		**[b]0.014***
	Postoperative 3rd month – 12th month		[b]0.933
Local kyphosis angle (LKA)	Preoperative	-20 - 34 (13.5)	9.61 ± 17.86
	Postoperative	-26 - 23 (11.5)	6.33 ± 16.00
	Postoperative 3rd month	-27 - 23 (10.5)	5.28 ± 15.88
	Postoperative 12th month	-26 - 30 (10.5)	5.50 ± 16.95
	p	**[a]0.001****	
	Preoperative - Postoperative		[b]0.059
	Preoperative - Postoperative 3rd month		**[b]0.001****
	Preoperative - Postoperative 12th month		**[b]0.001****
	Postoperative - Postoperative 3rd month		[b]0.169
	Postoperative - Postoperative 12th month		[b]0.560
	Postoperative 3rd month – 12th month		[b]1.000
Collapse	Preoperative	15 - 65 (28.5)	32.56 ± 13.13
	Postoperative	6 - 44 (12)	17.72 ± 10.27
	Postoperative 3rd month	8 - 42 (12.5)	17.17 ± 9.08
	Postoperative 12th month	9 - 45 (13.5)	19.00 ± 9.59
	p	**[a]0.001****	
	Preoperative - Postoperative		**[b]0.001****
	Preoperative - Postoperative 3rd month		**[b]0.001****
	Preoperative - Postoperative 12th month		**[b]0.049***
	Postoperative - Postoperative 3rd month		[b]1.000
	Postoperative - Postoperative 12th month		**[b]0.009****
	Postoperative 3rd month – 12th month		**[b]0.027***

*[a]Kruskal Wallis Test, [b]Bonferroni Dunn Test, *p<0.05, **p<0.01.*

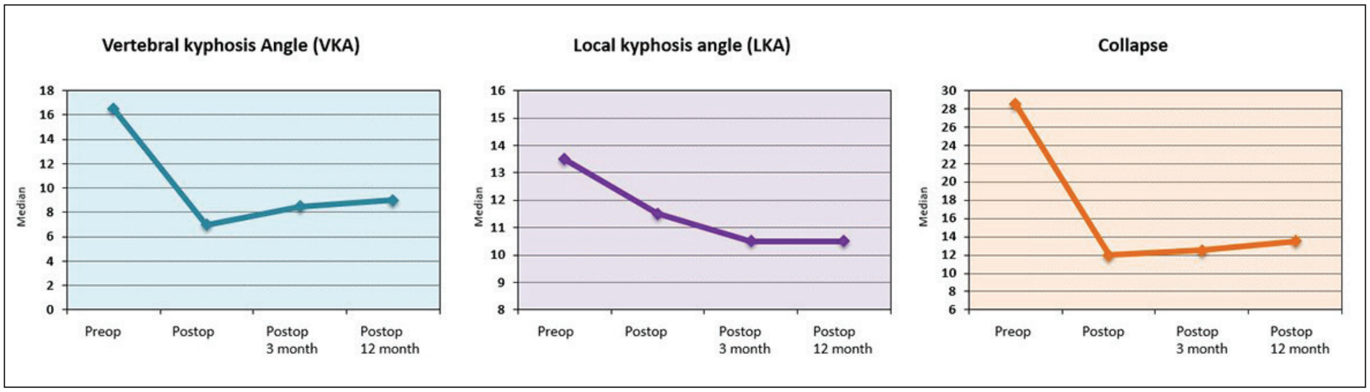

Figure 4: The distribution of the vertebral kyphosis angle, local kyphosis angle, and percentage of collapse measurements during follow-up.

DISCUSSION

Osteoporotic VCF is an increasing worldwide problem that is treated with different methods. Different patient indications determine which treatment (conservative or surgical) is optimal. Discrepancies in the treatments selected are probably due to our deficient understanding of the biomechanics of osteoporotic VCF. In recent years, increasing cement augmentation procedures have been applied, particularly for osteoporotic VCF (16).

Thoracolumbar fracture classification systems are designed for traumatic fractures. However, the kinetics and biomechanical properties of osteoporotic VCF might differ from those of traumatic cases. Moreover, the structural differences between young and elderly patients might significantly affect the healing process. Younger patients have good muscle support, and the alignment of the spinal column is usually normal. However, elderly patients have weak muscle support, and as natural kyphosis already exists, the risk of kyphosis progression is high following an osteoporotic VCF. Vertebral height loss after compression fracture might cause alterations in the sagittal spinal alignment and thus segmental instability (4). If the vertebral height is not effectively restored during KP, then there is an unbalanced load sharing across the spine (9). Moreover, the degree of the kyphotic angle after initial fracture is proportional to the formation of new fractures due to segmental instability (8). Such phenomena might explain why some studies have reported fracture progression and instability risk following cement application (8,9).

In recent years, Schnake et al. of the Spine Section of the German Society for Orthopedics and Trauma described a novel "Osteoporotic Fracture" classification system for osteoporotic VCF (13).

Regarding these data, one should keep in mind that some osteoporotic VCFs are unstable. The anterior and middle column support with cement augmentation might not effectively stabilize the unstable segment. Thus, after KP, there is a risk of complications in adjacent vertebral segments, such as reduction of vertebral height, corpus fracture, and segmental kyphosis (6). The development of these complications might result in segmental instability.

KP with the short segment stabilization method has been described for unstable traumatic thoracolumbar fractures. In 2006, Wang et al. compared the results of fusion (30 patients) versus non-fusion (28 patients) groups in surgically treated burst fractures of the thoracolumbar spine (18). The authors showed satisfactory outcomes with short-segment fixation without fusion, and 23 out of 28 patients in the non-fusion group underwent implant removal 1 year after surgery to save motion segments. A similar technique has been described for the surgical treatment of unstable osteoporotic VCF. In 2019, Spiegl et al. reported satisfactory outcomes with hybrid stabilization of unstable osteoporotic thoracolumbar vertebral body fractures. The authors retrospectively studied the clinical and radiological outcomes of 113 patients. They performed KP of the fractured vertebra, followed by short-segment posterior stabilization with cement augmentation. The authors applied cement augmentation to intact adjacent vertebrae to diminish the risk of screw cutout and impaired local alignment. They concluded that most of the patients had low or moderate limitations and low-to-moderate reduction loss that offered good outcomes (15). The PDS concept is a relatively new technique. However, the use of this method is increasing.

Biomechanical Perspective

Bozkus et al. compared the biomechanical properties of the dynamic (hinged) screw–rigid rod constructs with rigid screw–rigid rod constructs (1). The authors concluded that the dynamic system offered less stress shielding and allowed motion that was closer to normal motion than that allowed by the rigid system. We have compared the biomechanical properties of three different stabilization methods in a cadaver and finite element study: a) rigid screw–rigid rod, b) dynamic (hinged) screw–rigid rod, and c) dynamic (hinged) screw–dynamic rod. All stabilization methods effectively stabilized the unstable segment. However, the dynamic screw–dynamic rod method resulted in the best stabilization of the unstable segment that best mimicked normal kinetics (11).

CONCLUSION

In the study presented here, we have used the PDS method with KP to treat unstable osteoporotic VCF. The retrospective analysis of the patients showed that all patients exhibited unstable fractures as per the “Osteoporotic Fractures” classification system (Table I) (13).

We observed satisfactory outcomes regarding clinical and radiological parameters (Table II). PDS effectively stabilized the unstable segment with KP. In our study with the limited sample size, few complications were observed. We observed adjacent segment fracture only in three patients (5% of all patients). In the literature, the incidence of adjacent vertebral fracture after KP ranges from 3% to 29% (5,7). Spiegl et al. reported 17.4% further osteoporotic VCF with hybrid stabilization (15). We did not encounter any screw loosening or breakage in our cases. These relatively good outcomes regarding adjacent segment problems and construct-related complications might be due to the low sample size of our study, a limited follow-up period, and/or effective osteoporosis treatment following surgery.

The advantages of this method are as follows: a) it allows minimally invasive procedure with minimum iatrogenic soft tissue injury; b) KP offers augmentation of the anterior and middle column with the restoration of vertebral height; c) PDS effectively stabilizes the unstable segment; d) PDS provides better load sharing principle, and thus the load applied to screws is lower, resulting in lower device problems; and e) PDS preserves some motion at the adjacent segments, thus eliminating the necessity to remove the construct after bone healing.

The surgical method presented here for osteoporotic VCF is a promising technique; however, it must be studied and evaluated in larger patient groups and with longer follow-up periods.

REFERENCES

1. Bozkus H, Senoglu M, Baek S, Sawa AG, Ozer AF, Sonntag VK, Crawford NR: Dynamic lumbar pedicle screw-rod stabilization: In vitro biomechanical comparison with standard rigid pedicle screw-rod stabilization. J Neurosurg Spine 12(2):183-189, 2010
2. Denis F: The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine (Phila Pa 1976) 8:817-831, 1983
3. Di Silvestre M, Lolli F, Bakaloudis G, Parisini P: Dynamic stabilization for degenerative lumbar scoliosis in elderly patients. Spine (Phila Pa 1976) 35(2):227-234, 2010
4. Donnally III CJ, DiPompeo CM, Varacallo M: Vertebral Compression Fractures. [Updated 2020 Mar 25]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing, 2020 https://www.ncbi.nlm.nih.gov/books/NBK448171/
5. Garfin SR: A retrospective review of early outcomes of balloon kyphoplasty. In: North American Spine Society, (ed). Annual Meeting; 16th, Seattle, WA: North American Spine Society, 2001: 63
6. Harrop JS, Prpa B, Reinhardt MK, Lieberman I: Primary and secondary osteoporosis’ incidence of subsequent vertebral compression fractures after kyphoplasty. Spine (Phila Pa 1976) 29(19):2120-2125, 2004
7. Hyde JA, Feinberg J: Secondary Osteoporotic Compression Fractures after Kyphoplasty. Paper presented at: 70th Annual Meeting of the American Academy of Orthopedic Surgeons; New Orleans: LA, 2003:5–9
8. Kim HS, Ju CI: Spinal instability predictive scoring system for subsequent fracture after bone cement augmentation in patients with osteoporotic vertebral compression fracture. World Neurosurg 106:736-745, 2017
9. Li Q, Xiao L, Zhang J, Fan J, Zhou W, Yin G, Ren Y: The impact of endplate fracture on postoperative vertebral height loss and kyphotic deformity during treatment of osteoporotic vertebral compression fractures with balloon kyphoplasty. J Biomed Res 30(5):419-426, 2016
10. Nguyen HV, Ludwig S, Gelb D: Osteoporotic vertebral burst fractures with neurologic compromise. J Spinal Disord Techniques 16:10-19, 2003
11. Oktenoglu T, Erbulut DU, Kiapour A, Ozer AF, Lazoglu I, Kaner T, Sasani M, Goel VK: Pedicle screw-based posterior dynamic stabilisation of the lumbar spine: In vitro cadaver investigation and a finite element study. Comput Methods Biomech Biomed Engin 18(11):1252-1261, 2015
12. Old JL, Calvert M: Vertebral compression fractures in the elderly. Am Fam Physician 69(1):111-116, 2004
13. Schnake KJ, Blattert TR, Hahn P, Franck A, Hartmann F, Ullrich B, Verheyden A, Mörk S, Zimmermann V, Gonschorek O, Müller M, Katscher S, Saman AE, Pajenda G, Morrison R, Schinkel C, Piltz S, Partenheimer A, Müller CW, Gercek E, Scherer M, Bouzraki N, Kandziora F; Spine section of the German Society for orthopaedics and trauma: Classification of osteoporotic thoracolumbar spine fractures: Recommendations of the spine section of the German Society for orthopaedics and trauma (DGOU). Global Spine J 8:46-49, 2018
14. Silverman SL: The clinical consequences of vertebral compression fracture. Bone 13:27–31, 1992
15. Spiegl UJ, Anemüller C, Jarvers JS, von der Höh N, Josten C, Heyde CE: Hybrid stabilization of unstable osteoporotic thoracolumbar vertebral body fractures: Clinical and radiological outcome after a mean of 4 years. Eur Spine J 28(5):1130-1137, 2019.
16. Teyssédou S, Saget M, Pries P: Kyphopasty and vertebroplasty. Orthop Traumatol Surg Res 100:169-179, 2014
17. Vaccaro AR, Oner C, Kepler CK, Dvorak M, Schnake K, Bellabarba C, Reinhold M, Aarabi B, Kandziora F, Chapman J, Shanmuganathan R, Fehlings M, Vialle L; AOSpine Spinal Cord Injury & Trauma Knowledge Forum: AOSpine thoracolumbar spine injury classification system: Fracture description, neurological status, and key modifiers. Spine (Phila Pa 1976) 38(23):2028-2037, 2013
18. Wang ST, Ma HL, Liu CL, Yu WK, Chang MC, Chen TH: Is fusion necessary for surgically treated burst fractures of the thoracolumbar and lumbar spine? A prospective, randomized study. Spine (Phila Pa 1976) 31(23):2646-2652, 2006
19. Wood KB, Li W, Lebl DR, Ploumis A: Management of thoracolumbar spine fractures. Spine J 14:145–164, 2014
20. Zairi F, Court C, Tropiano P, Charles YP, Tonetti J, Fuentes S, Litrico S, Deramond H, Beaurain J, Orcel P, Delecrin J, Aebi M, Assaker R; French Society of Spine Surgery: Minimally invasive management of thoraco-lumbar fractures: Combined percutaneous fixation and balloon kyphoplasty. Orthop Traumatol Surg Res 98:105-111, 2012