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Comparison of Percutaneous Vertebroplasty and Kyphoplasty with Open Surgery in Vertebral Compression Fractures

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ABSTRACT

Background: Vertebral compression fractures (VCFs) from osteoporosis or malignancy cause severe pain and disability. While open surgery (instrumented decompression/fusion) is the traditional "gold standard," minimally invasive vertebral augmentation (percutaneous vertebroplasty (PVP) and balloon kyphoplasty (KP) offers rapid pain relief with less morbidity. We prospectively compared PVP/KP versus open surgery in VCF patients on pain relief, mobilization, and functional outcomes.

Methods: Sixty patients with acute thoracolumbar VCFs were randomized: Group A (n=30) underwent PVP/KP under sedation, and Group B (n=30) underwent open surgery. Inclusion criteria included symptomatic one- or two-level thoracolumbar fractures without neurological deficits. Outcomes included visual analogue scale (VAS) pain scores, time to mobilization, duration of analgesia, and Nottingham Pain Profile (NPP) domains.

Results: Groups were demographically similar in age (mean ~51 vs 53 years, p=0.19) and sex ratio (male 96.7% vs 100%, p=0.313). Most patients were urban-dwelling with low socioeconomic status (SES) (no difference in SES distribution, p=0.573). Both treatments produced significant pain reduction. Mean preoperative VAS was ~8.1 in both groups, falling to 2.47±0.51 in the PVP/KP group and 3.10±0.80 in the open-surgery group at 6 months. The PVP/KP group had consistently lower VAS scores at 1, 3, and 6 months (all p<0.001). Group A achieved markedly earlier mobilization (mean 1.97±0.72 days vs 4.33±1.63 days; p<0.001) and longer duration of pain relief (6.13±1.76 vs 5.10±1.86 months; p=0.031). NPP analysis showed dramatic improvement in pain, sleep, physical ability, and emotional domains after PVP/KP, with significantly lower post-treatment scores than in open surgery (e.g. NPP pain: 15.33±8.76 vs 25.83±13.51, p=0.001). Both groups improved on all NPP domains, but the minimally invasive group had better scores in nearly every category.

Conclusion: In VCF patients, percutaneous vertebral augmentation yielded faster pain relief, earlier mobilization, and superior short-term functional outcomes than open surgery, with significantly lower pain and better quality-of-life scores. These findings support the clinical adoption of PVP/KP in appropriately selected VCF patients.

Keywords: Vertebroplasty, Kyphoplasty, Vertebral compression fracture, Pain relief, minimally invasive spine surgery, Anaesthesia

INTRODUCTION

Osteoporotic and neoplastic vertebral compression fractures (VCFs) are increasingly common in aging populations and cause chronic pain, kyphosis, and reduced quality of life. Historically, treatment options ranged from bed rest and analgesics to major decompressive and reconstructive spinal surgery. In recent decades, percutaneous vertebroplasty and balloon kyphoplasty emerged as minimally invasive alternatives to stabilize the fracture, restore height, and relieve pain. These vertebral augmentation techniques (first described by Galibert et al. in 1987 and Lapras et al. in 1989) involve injecting polymethylmethacrylate (PMMA) cement into the collapsed vertebral body under imaging guidance. Early studies reported high rates of immediate pain relief with PVP/KP and low complication rates. However, open surgery (laminectomy, corpectomy, or instrumentation) remains the "gold standard" for more severe or unstable fractures. No large randomized trials directly compare these approaches.

Aim: We conducted a prospective randomized study to compare PVP/KP with open surgery in patients with vertebral compression fractures. The primary goals were to compare time to pain relief (VAS) and mobilization, while secondary goals included quality-of-life outcomes, hospital stay, and costs.

Rationale: Minimally invasive PVP/KP, typically done under sedation, may avoid the extensive tissue trauma and prolonged recovery of open surgery. If PVP/KP achieves comparable pain control, it could reduce perioperative morbidity and accelerate functional recovery. This study addresses a gap in head-to-head comparisons of PVP/KP versus open surgery in VCF, especially relevant for anesthesia and pain practice.

MATERIALS & METHODS

We conducted a prospective, randomized trial at a tertiary hospital from Dec 2019 to Oct 2021. Patients presenting with acute symptomatic thoracolumbar VCFs (traumatic or osteoporotic) were screened. Inclusion criteria were: age >18, one or two contiguous vertebral fractures confirmed radiographically, localized back pain with percussion tenderness, intact posterior vertebral wall, and no neurological deficits. Exclusion criteria included coagulopathy, active infection, severe comorbidities, or lesions extending beyond the vertebral body (posterior element involvement, spinal cord compression). Eligible patients were randomized by closed-envelope draw into two groups of 30 each: Group A underwent percutaneous vertebroplasty or balloon kyphoplasty, and Group B underwent open surgical treatment (decompression and stabilization).

Anesthesia: Group A procedures were performed under conscious sedation with local anesthesia, per our institutional protocol. Patients were monitored and sedated to comfort during fluoroscopically guided cement injection. Group B patients underwent standard general anesthesia and posterior instrumentation techniques (laminectomy or corpectomy with internal fixation) as indicated.

Procedure (Group A): The PVP/KP procedure followed published steps. In brief, patients were placed prone and sedated. After local anesthetic infiltration, bilateral transpedicular needles were advanced into the vertebral body under C-arm guidance. For kyphoplasty, inflatable balloons were inserted to restore height (if needed), then deflated. High-viscosity PMMA cement was slowly injected under fluoroscopy until adequate fill was achieved. Needles were withdrawn and the small skin incision was closed. Patients

remained supine for one-hour post-procedure, then were mobilized as tolerated.

Postoperative Care: All patients were monitored in recovery with standard vital signs and analgesia. Analgesic requirements were recorded. Patients in both groups followed identical postoperative mobilization protocols for fairness of comparison.

Outcomes and Data Collection: Primary outcomes were VAS pain score (0–10) and time to first mobilization. VAS was recorded preoperatively and at 1-, 3-, and 6-months post-procedure. Secondary outcomes included duration of analgesia (time until additional pain treatment needed), Nottingham Pain Profile (NPP) scores, and socioeconomic variables (residence, SES). The Nottingham Pain Profile is a validated pain/disability questionnaire with domains for pain intensity, emotional reactions, sleep, physical ability, and social isolation. We also recorded total hospital stay, complications, and direct costs.

Statistical Analysis

Continuous data were expressed as mean ± SD and compared by Student's t-test. Categorical data (e.g. sex distribution) were compared by chi-square test. A p-value <0.05 was considered significant. Intragroup changes over time were analysed by repeated-measures ANOVA.

RESULT

The mean age of the group A was 50.33±6.69 years while the mean age of the group B was 52.83±7.88 years. No significant difference was present in mean ages between the groups (p=0.190)

Table – 1: Descriptive Summary of Age of Study Cases

Group	Group A		Group B		unpaired t test	
	Mean	SD	Mean	SD	t-value	p-value
Age (in years)	50.33	6.69	52.83	7.88	-1.33	0.190

Table – 2: Distribution of Cases according to Sex

Variable		Group A		Group B		chi sq	p-value
		No.	%	No.	%		
Sex	Male	29	96.7%	30	100.0%	1.02	0.313
	Female	1	3.3%	0	0.0%		
Total		30	100.0%	30	100.0%		

The male – female proportion in group A was 96.7%: 3.3% while in group B this proportion was 100%: 0.0%. No significant difference was found in male – female proportion between the groups (p=0.313).

Table – 3: Distribution of Cases according to Place

Variable		Group A		Group B		chi sq	p-value
		No.	%	No.	%		
Place	Urban	23	76.7%	30	100.0%	7.93	0.005
	Rural	7	23.3%	0	0.0%		
Total		30	100.0%	30	100.0%		

The urban – rural proportion in group A was 76.7%: 23.3% while in group B this proportion was 100%: 0.0%. The significant difference was found in urban – rural proportion between the groups (p=0.005).

Table – 4: Distribution of Cases according to Socioeconomic Status

Variable		Group A		Group B		chi sq	p-value
		No.	%	No.	%		
Socioeconomic Status	Low	20	66.7%	22	73.3%	0.32	0.573
	Middle	10	33.3%	8	26.7%		
Total		30	100.0%	30	100.0%		

The proportion of low and middle classes in group A was 66.7%: 33.3% while in group B this proportion was 73.3%: 26.7%. No significant difference was found in SES categories between the groups (p=0.573).

Table – 5: Intergroup and Intragroup Comparison of VAS

VAS	Group A		Group B		unpaired t test	
	Mean	SD	Mean	SD	t-value	p-value
Before procedure	8.07	0.87	8.27	0.74	-0.96	0.341
At one month	2.63	0.61	3.63	0.89	-5.06	<0.001
At three months	2.40	0.50	3.23	0.77	-4.96	<0.001
At six months	2.47	0.51	3.10	0.80	-3.65	0.001
Intragroup	F=610.55, p<0.001		F=458.84, p<0.001			

In group A the mean VAS score before procedure was 8.07±0.87 which was reduced at one month and further reduced onwards and finally after six months the mean VAS score was 2.47±0.51. In group B the mean VAS score before procedure was 8.27±0.74 which was reduced at one month and further reduced onwards and finally after six months the mean VAS score was 3.10±0.80. No significant difference was present before procedure (p=0.341), but then the difference was found at 1 month (p<0.001), 3 month (p<0.001) and 6 months (p<0.001). In all these situations the mean VAS score of group A was less than the group B.

Table – 6: Intergroup Comparison of Duration of Pain relief and Onset of Mobilization

Variable	Group A		Group B		unpaired t test	
	Mean	SD	Mean	SD	t-value	p-value
Duration of pain relief (months)	6.13	1.76	5.10	1.86	2.21	0.031
Onset of mobilization (days)	1.97	0.72	4.33	1.63	-7.29	<0.001

The mean duration of pain relief in group A was 6.13±1.76 months while the mean duration of pain relief in group B was 5.10±1.86 months. The significant difference was found in mean duration of pain relief between the groups (p=0.031). The onset of mobilization in group A was 1.97±0.72 days while the mean onset of mobilization in group B was 4.33±1.63 days. The significant difference was found in mean onset of mobilization between the groups (p<0.001).

Table – 7: Intergroup and Intragroup Comparison of Pain

Pain	Group A		Group B		unpaired t test	
	Mean	SD	Mean	SD	t-value	p-value
Before Procedure	85.22	5.93	86.69	5.57	-0.99	0.327
After Procedure	15.33	8.76	25.83	13.51	-3.57	0.001
Intragroup	t=33.34, p<0.001		t=23.45, p<0.001			

Before procedure the mean pain score in group A was 85.22±5.93 while the mean pain score of group B was 86.69±5.57. No significant difference was found in mean pain score between the groups (p=0.327). After procedure the mean pain score in group A was 15.33±8.76 while the mean pain score of group B was 25.83±13.51. The significant difference was found in mean pain score between the groups (p=0.001). The significant change was observed in pain score in both the groups (p<0.001).

Table – 8: Intergroup and Intragroup Comparison of Energy Level

Energy Level	Group A		Group B		unpaired t test	
	Mean	SD	Mean	SD	t-value	p-value
Before Procedure	67.05	7.00	68.35	6.86	-0.72	0.473
After Procedure	0.27	0.19	0.27	0.22	-0.01	0.995
Intragroup	t=91.96, p<0.001		t=54.39, p<0.001			

Before procedure the mean energy level score in group A was 67.05±7.00 while the mean energy level score of group B was 68.35±6.86. No significant difference was found in mean energy level score between the groups (p=0.473). After procedure the mean energy level score in group A was 0.27±0.19 while the mean energy level score of group B was 0.27±0.22. No significant difference was found in mean energy level score between the groups (p=0.995). The significant change was observed in energy level score in both the groups (p<0.001).

Table – 9: Intergroup and Intragroup Comparison of Emotional Reaction

Emotional reaction	Group A		Group B		unpaired t test	
	Mean	SD	Mean	SD	t-value	p-value
Before Procedure	81.64	6.19	83.15	5.00	-1.04	0.303
After Procedure	9.48	2.75	15.71	5.61	-5.46	<0.001
Intragroup	t=55.62, p<0.001		F=45.96, p<0.001			

Before procedure the mean emotional reaction score in group A was 81.64±6.19 while the mean emotional reaction score of group B was 83.15±5.00. No significant difference was found in mean emotional reaction score between the groups (p=0.303). After procedure the mean emotional reaction score in group A was 9.48±2.75 while the mean emotional reaction score of group B was 15.71±5.61. The significant difference was found in mean emotional reaction score between the groups (p<0.001). The significant change was observed in emotional reaction score in both the groups (p<0.001).

Table – 10: Intergroup and Intragroup Comparison of Sleep

Sleep	Group A		Group B		unpaired t test	
	Mean	SD	Mean	SD	t-value	p-value
Before Procedure	85.95	8.95	87.25	9.00	-0.56	0.576
After Procedure	13.16	7.52	32.55	14.37	-6.55	<0.001
Intragroup	t=39.60, p<0.001		t=19.07, p<0.001			

Before procedure the mean sleep score in group A was 85.95±8.95 while the mean sleep score of group B was 87.25±9.00. No significant difference was found in mean sleep score between the groups (p=0.576). After procedure the mean sleep score in group A was 13.16±7.52 while the mean sleep score of group B was 32.55±14.37. The significant difference was found in mean sleep score between the groups (p<0.001). The significant change was observed in sleep score in both the groups (p<0.001).

Table – 11: Intergroup and Intragroup Comparison of Physical Ability

Physical ability	Group A		Group B		unpaired t test	
	Mean	SD	Mean	SD	t-value	p-value
Before Procedure	85.77	5.30	87.22	5.27	-1.07	0.291
After Procedure	11.03	2.21	23.29	8.21	-7.90	<0.001
Intragroup	t=80.24, p<0.001		t=34.88, p<0.001			

Before procedure the mean physical ability score in group A was 85.77±5.30 while the mean physical ability score of group B was 87.20±5.27. No significant difference was found in mean physical ability score between the groups (p=0.291). After procedure the mean physical ability score in group A was 11.03±2.21 while the mean physical ability score of group B was 23.29±8.21. The significant difference was found in mean physical ability score between the groups (p<0.001). The

significant change was observed in physical ability score in both the groups (p<0.001).

Table – 12: Intergroup and Intragroup Comparison of Social Isolation

Social Isolation	Group A		Group B		unpaired t test	
	Mean	SD	Mean	SD	t-value	p-value
Before Procedure	82.02	1.72	82.34	1.72	-0.72	0.476
After Procedure	19.05	3.91	27.33	7.35	-5.45	<0.001
Intragroup	t=75.26, p<0.001		t=41.22, p<0.001			

Before procedure the mean social isolation score in group A was 82.02±1.72 while the mean social isolation score of group B was 82.34±1.72. No significant difference was found in mean social isolation score between the groups (p=0.476). After procedure the mean social isolation score in group A was 19.05±3.91 while the mean social isolation score of group B was 27.33±7.35. The significant difference was found in mean social isolation score between the groups (p<0.001). The significant change was observed in social isolation score in both the groups (p<0.001).

Table – 13: Intergroup Comparison of DN4 and DSM4 Questionnaire Scores

Variable	Group A		Group B		unpaired t test	
	Mean	SD	Mean	SD	t-value	p-value
DN 4 Questionnaire	2.03	0.93	3.97	0.96	-7.91	<0.001
DSM 4 Symptom Questionnaire	8.73	2.90	16.00	4.76	-7.15	<0.001

The DN4 questionnaire in group A was 2.03±0.93 while in group B the mean was 3.97±0.96. The significant difference was found in mean DN4 score between the groups (p<0.001). The DSM4 questionnaire in group A was 8.73±2.90 while in group B the mean was 16.00±4.76. The significant difference was found in mean DSM4 score between the groups (p<0.001).

Table – 14: Intergroup Comparison of Duration of Stay and Cost

Group	Group A		Group B		unpaired t test	
	Mean	SD	Mean	SD	t-value	p-value
DURATION OF STAY	3.27	0.78	6.03	0.89	-12.77	<0.001
COST	30133.33	819.31	44900.00	547.72	-82.07	<0.001

The mean duration of stay in group A was 3.27±0.78 while in group B the mean duration of stay was 6.03±0.89. The significant difference was found in mean duration of stay between the groups (p<0.001). The mean cost in group A was Rs 30133±819 while in group B the mean cost was Rs 44900±548.The significant difference was found in mean cost between the groups (p<0.001).

Table – 15: Intergroup Comparison of Complication

Variable		Group A		Group B		chi sq	p-value
		No.	%	No.	%		
Complications	No	30	100.0%	30	100.0%	NA	NA
Total		30	100.0%	30	100.0%		

No complication was observed in any case of both groups.

Table – 16: Intergroup Comparison of Analgesic Intake

Analgesic Intake		Group A		Group B		chi sq	p-value
		No.	%	No.	%		
Before procedure	Yes	30	100.0%	30	100.0%	NA	NA
12 hrs	Yes	30	100.0%	30	100.0%	NA	NA
1 day	Yes	30	100.0%	30	100.0%	NA	NA
1 week	No	22	73.3%	7	23.3%	15.02	<0.001
	Yes	8	26.7%	23	76.7%		
1 month	No	30	100.0%	26	86.7%	4.29	0.038
	Yes	0	0.0%	4	13.3%		
3 months	No	30	100.0%	27	90.0%	3.16	0.076
	Yes	0	0.0%	3	10.0%		
6 months	No	30	100.0%	29	96.7%	1.02	0.313
	Yes	0	0.0%	1	3.3%		

Before procedure and after 12 hrs and 1 day the analgesic intake was taken in all the cases of both groups. After 1 week the analgesic intake was taken in 26.7% of group A and 76.7% of group B. The significant difference was found in analgesic intake between the groups ($p<0.001$). After 1 month the analgesic intake was taken in 0.0% of group A and 13.3% cases of group B. The significant difference was found in analgesic intake between the groups ($p=0.038$). After 3 month the analgesic intake was taken in 0.0% of group A and 10% cases of group B. No significant difference was found in analgesic intake between the groups ($p=0.076$). After 6 month the analgesic intake was taken in 0.0% of group A and 3.3% cases of group B. No significant difference was found in analgesic intake between the groups ($p=0.313$).

DISCUSSION

Our study demonstrates that percutaneous vertebral augmentation (PVP/KP) provides faster and more durable pain relief, and earlier return to mobility, than traditional open surgery for VCF. The majority of Group A patients experienced immediate, dramatic pain reduction, consistent with literature reports of ~90% early pain relief after PVP. Group A's 6-month VAS (~2.5) was significantly lower than Group B's (~3.1), indicating not only rapid analgesia but also slightly better long-term control. Similarly, prior reviews noted high pain-response rates for PVP and KP. Hulme et al. found 87% pain relief after vertebroplasty and 92% after kyphoplasty, and Jensen et al. reported significant immediate relief in 90% of patients. Our results align with these findings and extend them by direct comparison to open surgery.

Crucially, patients in the PVP/KP group mobilized on average within 2 days versus 4–5 days after open surgery. This earlier ambulation likely reflects the percutaneous approach's minimal muscle disruption. Faster mobilization can reduce complications of bedrest and improve patient confidence. The longer duration of pain relief (by ~1 month) also favored PVP/KP, perhaps due to immediate vertebral stabilization. In contrast, open surgery often involves instrumentation and fusion, which, while stabilizing the spine, entails more trauma and requires longer rehabilitation. Our findings suggest that, in suitable VCF cases, spinal augmentation should be considered first-line over invasive fusion surgery. This is consistent with emerging practice guidelines favoring early vertebral augmentation for intractable pain.

The Nottingham Pain Profile results underscore the broader quality-of-life benefit of PVP/KP. We observed significantly lower (better) scores in pain, emotional, sleep, physical, and social domains post-treatment. For example, Group A patients reported far less sleep disturbance and emotional distress after vertebroplasty than the open-surgery group. Such improvements likely stem from reduced pain and quicker recovery. These

outcomes reinforce that vertebral augmentation not only relieves pain but also meaningfully restores function and well-being. Previous trials have emphasized improved functional status after PVP/KP, and our data add domain-specific evidence using the NPP.

In anesthetic practice, these results advocate using conscious sedation and local anesthesia when performing vertebral augmentation. Our high satisfaction and safety in Group A mirror reports that PVP/KP can be done efficiently without general anesthesia. The avoidance of intubation and muscle relaxants benefits older patients with comorbidities. Conversely, the open surgery group required full general anesthesia with longer operative times, which may carry higher perioperative risks.

Clinical relevance: For anesthesiologists and pain specialists, recognizing the efficacy of vertebral augmentation is important. Rapid pain relief reduces opioid needs and hospital stays, and avoiding open surgery spares patients' blood loss and wound-related complications. Our finding of no major neurological or cement-embolism complications highlights that, when performed by experienced teams, PVP/KP is safe. Routine use of high-viscosity cement and careful technique, as in our protocol, likely minimized leaks.

Limitations

This was a single-center study with a modest sample. Long-term follow-up beyond 6 months is needed to assess refracture rates and fusion outcomes. Also, while we randomized patients, group B had 100% males and all urban residents (reflecting referral bias), which may limit generalizability.

CONCLUSION

Percutaneous vertebroplasty/kyphoplasty proved superior to open surgical fixation in this cohort of vertebral compression fracture patients. The minimally invasive group achieved significantly faster and greater pain relief (VAS), earlier mobilization, and better functional status (NPP domains) than the open-surgery group. Given these advantages and lower morbidity, PVP/KP should be considered the preferred intervention for suitable osteoporotic or metastatic VCFs. Future work should focus on longer-term comparisons (beyond 1 year) and cost-effectiveness analyses, as well as refinements in anesthesia protocols to further improve recovery.

Declaration by Authors

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