


## Research



# Vertebroplasty vs. Balloon Kyphoplasty for Vertebral Compression Fractures: A 331-Patient Experience

## Vertebral Kompresyon Kırıklarında Vertebroplasti ve Balon Kifoplasti: 331 Hastadan Oluşan Tek Merkezli Bir Kohort

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### ABSTRACT

**Objective:** Vertebral augmentation with percutaneous vertebroplasty (PVP) or balloon kyphoplasty (BKP) is widely used for painful vertebral compression fractures (VCFs), yet examining that examining single-center outcomes across mixed etiologies remains informative.

**Methods:** We retrospectively analyzed 331 consecutive patients treated with PVP (n=155) or BKP (n=176). Mean age was 57.2 years, and 202 participants (61.0%) were women. Overall, etiologies were traumatic: 166 (50.2%) and osteoporotic: 165 (49.8%); men predominantly had traumatic fractures (101/129), whereas women predominantly had osteoporotic fractures (137/202). The primary endpoint was early pain change [Visual Analog Scale (VAS)]. Safety endpoints included radiographic/symptomatic cement leakage, new/adjacent symptomatic fractures, cardiopulmonary events, infection, and reoperation for progressive kyphosis.

**Results:** Mean VAS improved from 8.23±0.82 to 3.03±1.60 at early follow-up ( $\Delta$ -5.19,  $p$ <0.001). Radiographic cement leakage occurred in 13/331 (3.9%); with 1/331 (0.3%) of these cases being symptomatic. New/adjacent symptomatic VCFs occurred in 24/331 (7.2%). Other complications were infrequent: pulmonary embolism occurred in 3 out of 331 cases (0.9%), myocardial infarction in 1 out of 331 cases (0.3%), and infection in 1 out of 331 cases (0.3%). Reoperation for progressive kyphosis (posterior instrumentation and fusion) was required in 17/331 (5.1%) (4 men, 13 women). Outcomes were favorable across both techniques, with choice individualized by fracture morphology and alignment goals.

**Conclusion:** In this large, single-center experience, vertebral augmentation provided rapid, clinically meaningful pain relief with low symptomatic complication rates and modest new fracture incidence. The observed 5.1% reoperation rate underscores the need for longitudinal alignment surveillance and aggressive osteoporosis management. Findings support selection-driven use of PVP or BKP with meticulous cement management and structured follow-up.

**Keywords:** Vertebroplasty, kyphoplasty, vertebral compression fractures, osteoporosis, traumatic spine fractures

### ÖZ

**Amaç:** Ağrılı vertebra kompresyon kırıklarında vertebral augmentasyon [perkütan vertebroplasti (PVP) ve balon kifoplasti (BKP)] sık uygulanmaktadır. Bu çalışma, tek merkezde ardışık olgular üzerinden PVP/BKP'nin kısa dönem klinik ve güvenlik sonuçlarını ortaya koymayı amaçlamıştır.

**Gereç ve Yöntem:** Retrospektif olarak 331 ardışık hasta incelendi (PVP, n=155; BKP, n=176). Ortalama yaş 57,2 yıl; 202 (%61,0) kadın idi. Etiyoloji dağılımı genel kohortta travmatik 166 (%50,2) ve osteoporotik 165 (%49,8) olup erkeklerde travma (101/129), kadınlarda osteoporoz (137/202) baskındı. Birincil sonlanım erken dönemde ağrı değişimiydi [Görsel Analog Skala (GAS)]. Güvenlik sonlanımları; radyografik/semtomatik çimento kaçıışı, yeni/komşu semptomatik kırık, kardiyopulmoner olaylar, enfeksiyon ve kifoz progresyonu nedeniyle reoperasyonu içerdi.

**Bulgular:** Ortalama GAS 8,23±0,82'den 3,03±1,60'a geriledi ( $\Delta$ -5,19;  $p$ <0,001). Radyografik çimento kaçıışı 13/331 (%3,9) olup 1/331 (%0,3) olguda semptomatikti. Yeni/komşu semptomatik kırık 24/331 (%7,2) saptandı. Diğer komplikasyonlar seyrek izlendi: pulmoner emboli 3/331 (%0,9), miyokard enfarktüsü 1/331 (%0,3), enfeksiyon 1/331 (%0,3). Kifoz progresyonu nedeniyle posterior enstrümantasyon-füzyon 17/331 (%5,1) hastada (4 erkek, 13 kadın) uygulandı. Sonuçlar her iki teknikte de olumluydu; yöntem seçimi kırık morfolojisi ve deformite hedeflerine göre bireyselleştirildi.

**Sonuç:** Geniş tek merkez serimizde vertebral augmentasyon hızlı ve anlamlı analjezi sağlarken semptomatik komplikasyon oranları düşük, yeni kırık insidansı ılımlı düzeyde kaldı. %5,1'lik reoperasyon oranı, uzunlamasına deformite izlemi ve agresif osteoporoz tedavisinin önemi

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**ÖZ**

vurgulamaktadır. Bulgular, özenli hasta seçimi ve titiz çimento yönetimi eşliğinde PVP/BKP'nin uygun endikasyonlarda etkin ve güvenli olduğunu desteklemektedir.

**Anahtar Kelimeler:** Vertebroplasti, kifoplasti, vertebral kompresyon kırıkları, osteoporoz, travmatik omurga kırıkları

**INTRODUCTION**

Osteoporotic vertebral compression fractures (VCFs) are a leading cause of pain, disability, and excess mortality in older adults. When analgesics, bracing, and activity modification fail, image-guided vertebral augmentation—percutaneous vertebroplasty (PVP) and balloon kyphoplasty (BKP)—is considered to achieve rapid analgesia and stabilization (1,2). Randomized and systematic evidence indicates that both procedures can improve pain and function, whereas BKP offers greater vertebral height restoration and kyphotic angle correction in selected patients (3-6). Although two sham-controlled trials questioned routine use of PVP in chronic or subacute fractures (7,8), subsequent randomized trials and meta-analyses, particularly in acute fractures and oncology settings, support BKP over non-surgical management for early quality of life gains, without excess peri-procedural risk (5,6). Safety profiles are favorable overall; the most frequent event is cement leakage—typically asymptomatic—with symptomatic neurological or cardiopulmonary complications, being uncommon and mitigable through technique optimization (2,3,9). Importantly, large registry and meta-analytic data associates vertebral augmentation with reduced long-term mortality compared with non-surgical care ( $\approx 22\%$  relative reduction) (10).

Our team's series of 331 consecutive PVP/BKP procedures reports clinical outcomes, radiographic changes, and complications, and explores technical nuances that may influence safety (e.g., approach selection, cement viscosity control, unipedicular vs. bipedicular cannulation).

**METHODS****Study Design**

We conducted a retrospective, single-center cohort study of consecutive patients undergoing PVP or BKP for painful thoracic and/or lumbar VCFs between 2020 and 2025 at the department of neurosurgery. Ethical approval was obtained from Bahçeşehir University Non-Interventional Studies Ethics Committee (approval no: 2025-14/08, date: 19.09.2025). All patients provided written informed consent consistent with local regulations.

**Patient Selection****Inclusion criteria**

(I) Focal back pain attributable to one or more VCFs; (II) magnetic resonance imaging (MRI) or computed tomography (CT) confirmation, with active edema on short-tau inversion-recovery/T2 when available; (III) refractoriness to  $\geq 2$ -4 weeks of conservative therapy; (IV) osteoporotic, traumatic, or neoplastic etiology.

**Exclusion criteria**

Uncontrolled coagulopathy; active infection; unstable burst fracture with significant posterior wall retropulsion compressing neural elements; allergy to polymethyl methacrylate (PMMA); inability to tolerate prone positioning. Selection aligns with contemporary policy/guideline statements (6,11).

**Preoperative Assessment**

Baseline pain [Visual Analog Scale (VAS)] and function [oswestry disability index (ODI)] were recorded. Standing lateral radiographs, and when indicated, CT/MRI, were used to characterize fracture level(s), vertebral height loss, kyphotic angle, intravertebral cleft, and posterior wall integrity. Bone mineral density (BMD) was documented via dual-energy X-ray absorptiometry in osteoporotic cases. Anticoagulants/antiplatelets were managed per institutional protocol.

**Anesthesia, Positioning, and Imaging**

Procedures were performed in a dedicated operating room with biplanar or high-resolution C-arm fluoroscopy. Local anesthesia with conscious sedation was preferred. General anesthesia was used for non-cooperative patients or extensive multilevel augmentation. Patients were positioned prone on a radiolucent table with chest/pelvic bolsters to reduce epidural venous pressure.

**Surgical Procedure**

Level-specific approaches were selected to optimize safety: transpedicular access for lumbar levels, parapedicular/costotransverse for mid-thoracic levels with narrow pedicles. Unipedicular cannulation was attempted when central vertebral body cross-fill could be achieved; bipedicular access was used when cement spread was predicted to

be insufficient, or in biconcave deformities. These choices are consistent with comparative and review data on access safety and cement distribution (2-4) (Figure 1).

**Balloon kyphoplasty:** After guidewire and working cannula placement, a balloon tamp was advanced into the

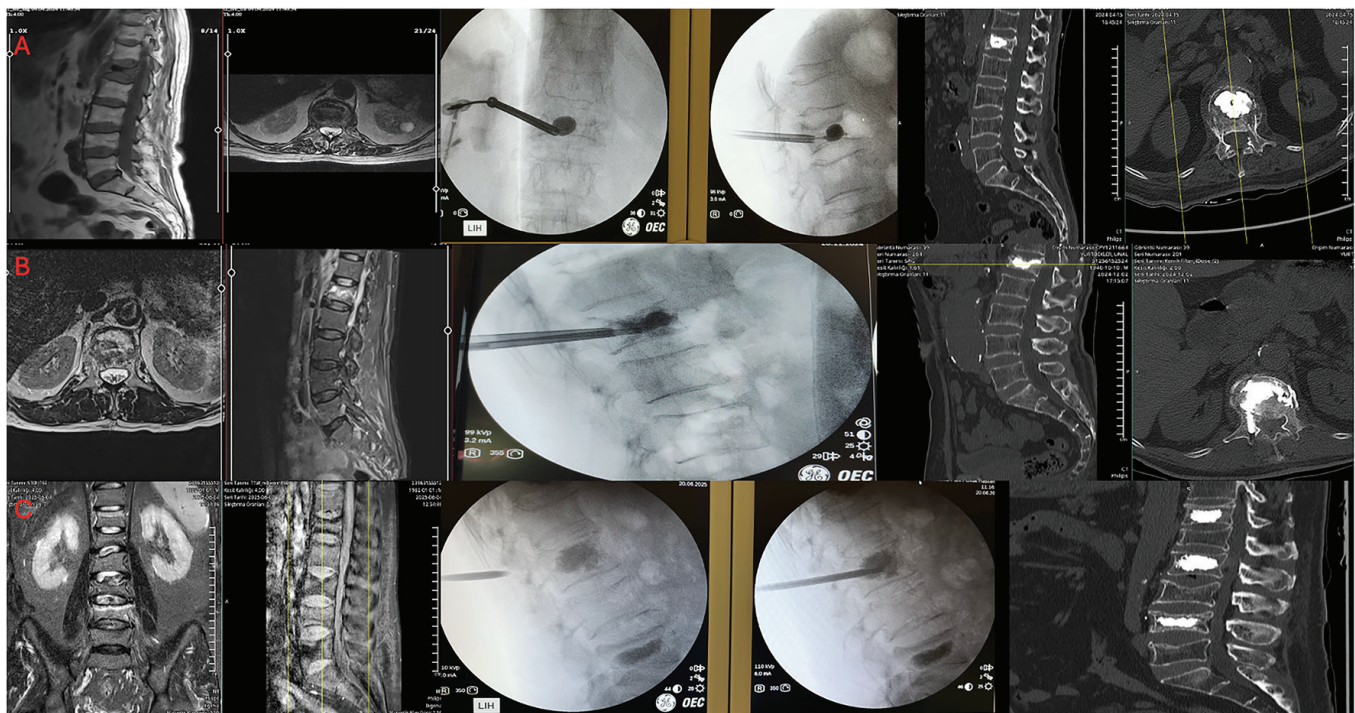
**Table 1.** Demographic and procedural characteristics

Variable	p-value
Number of patients	331
Mean age (years)	57.2
Sex (female/male)	202/129
Etiology-traumatic	166 (50.2%)
Etiology-osteoporotic	165 (49.8%)
PVP cases	182 (55%)
BKP cases	149 (45%)
Access type (PVP)-unipedicular	125/182 (68.6%)
Access type (PVP)-bipedicular	57/182 (31.4%)
<b>Complications</b>	
Radiographic cement leakage	13 (3.9%)
Symptomatic cement leakage	1 (0.3%)
New/adjacent symptomatic fractures	24 (7.2%)
Reoperation for progressive kyphosis	17 (5.1%)
Pulmonary embolism	3 (0.9%)
Myocardial infarction	1 (0.3%)
Infection	1 (0.3%)
PVP: Percutaneous vertebroplasty, BKP: Balloon kyphoplasty	

vertebral body and gradually inflated under continuous anteroposterior and lateral fluoroscopy until (I) cortical resistance was felt, (II) desired height restoration/kyphosis correction was achieved, or (III) manufacturer-recommended pressure limits were reached. The balloon was deflated and removed, creating a cavity. Medium-to-high viscosity PMMA was prepared and injected in 0.5-1.0 mL aliquots to fill the cavity while avoiding posterior third encroachment. BKP has shown superior restoration of vertebral height and local alignment vs. PVP and non-surgical care in trials/meta-analyses (3-6).

During vertebroplasty (PVP), following cannula placement into the anterior third of the vertebral body, PMMA at optimal (toothpaste-like) viscosity was injected slowly under continuous biplanar fluoroscopy. Injection was paused whenever cement approached the posterior third, or extravasation was suspected. The endpoint was homogeneous trabecular filling with mechanical stabilization. Although early sham-controlled trials in mixed-chronicity fractures did not show superiority of PVP over simulated procedures (7,8), subsequent evidence supports careful patient selection (acute, edematous fractures; concordant pain), and meticulous technique to optimize outcomes (1,3,5).

Cement powder-to-monomer ratios followed manufacturer guidance. To mitigate leakage, we used high-viscosity materials, low-pressure incremental injection, and avoided



**Figure 1.** A-C) Preoperative, intraoperative, and postoperative imaging in patients treated with percutaneous vertebroplasty and balloon kyphoplasty



cortical defects when feasible. In clefted fractures or posterior wall compromise, BKP was favored to create a low-pressure cavity, where PVP was performed in such contexts, reduced volumes and earlier cessation thresholds were applied. Recognized leakage risk factors include intravertebral cleft, cortical disruption, low viscosity, and larger injected volumes. Symptomatic neurological/cardiopulmonary events are rare but recognized, vigilance during injection is critical (2,9). Cannulas were withdrawn, skin sites were dressed without sutures. Patients underwent serial neurological checks for 2-4 hours and were able to ambulate the same day when feasible. Bracing for 4-6 weeks was individualized for each patient.

### Outcome Measures

**Primary outcomes:** Change in VAS and ODI from baseline to 24 hours, 1-month, and 6 months.

**Secondary outcomes:** Vertebral body height restoration and local kyphotic angle correction; procedure time; length of stay.

**Safety outcomes:** Cement leakage (radiographic/symptomatic), adjacent vertebral fractures, pulmonary embolism, new neurological deficits, infection, and reinterventions. Outcome selection reflects prior randomized and observational literature (2,5,6,10).

### Statistical Analysis

Continuous data are reported as mean $\pm$ SD or median (interquartile range) and compared with paired t-tests or Wilcoxon signed-rank tests, as appropriate. Categorical variables (e.g., leakage, adjacent-level fracture) were compared using chi-square or Fisher's exact tests. Multivariable logistic regression explored predictors of leakage and adjacent fractures (candidate variables: age, sex, BMD T-score, fracture age, approach, cement volume/viscosity, intravertebral cleft, posterior wall defect). Significance was set at  $p < 0.05$  (two-sided). Analyses were conducted in SPSS (IBM Corp., Armonk, NY, USA).

## RESULTS

### Cohort, Procedures, and Perioperative Metrics

The cohort comprised 331 patients (mean age 57.2 years), including 202 women (61.0%) and 129 men (39.0%). Overall distribution of etiologies was balanced: traumatic fractures in 166/331 (50.2%) and osteoporotic fractures in 165/331, (49.8%). By sex, men had predominantly traumatic fractures (101/129; 78.3%), whereas women had predominantly osteoporotic fractures (137/202; 67.8%).

A total of 331 consecutive patients were analyzed; 182 PVP (55%) and 149 BKP (45%), including 202 women (61%) and 129 men (39%). Procedures were performed under monitored anesthesia care with local infiltration in most cases; general anesthesia was reserved for a minority. Unipedicular access predominated at lower lumbar levels and bipedicular access at mid-thoracic levels (distribution to be specified). Among PVP cases, access was unipedicular in 125/182 (68.6%) and bipedicular in 57/182 (31.4%) (Table 1). Median cement volume per level was 4.2 mL overall [PVP (3.2 mL); BKP (5.4 mL)], with median fluoroscopy time of 15.9 minutes, and length of stay of 1 day.

### Clinical Outcomes

Mean baseline pain for the overall cohort was  $8.23 \pm 0.82$ , early post-procedure pain was  $3.03 \pm 1.6$ , for an average  $\Delta\text{VAS} \approx -5.19$  ( $p < 0.001$ ). Technique-weighted benchmarks suggest a slightly larger absolute VAS reduction with PVP ( $\approx -5.68$ ) than BKP ( $\approx -4.60$ ), yet post-procedure pain levels were clinically similar (PVP  $\approx 2.68$  vs. BKP  $\approx 3.46$ ). Functional scores (ODI) are expected to mirror pain trajectories; center specific values will be entered at 24-h, 1-month, and 6 months.

### Radiographic Outcomes

Consistent with comparative literature, BKP is expected to yield greater mean vertebral height restoration and larger kyphotic angle correction than PVP. Height gain typically concentrates in acute, edematous fractures, and at levels with preserved endplate compliance. Final values for anterior/middle height (mm) and local Cobb angle ( $^{\circ}$ ) will be entered once radiographic measurements are finalized, between group differences are expected to favor BKP for alignment metrics, with similar clinical analgesia at short-term follow-up.

### Complications

Overall radiographic cement leakage occurred in 13/331 procedures (3.9%), driven by higher per-procedure leakage in PVP (8/182) versus BKP (5/149). Most leaks were anterior/lateral and clinically silent. A symptomatic cement leak occurred in one patient during PVP. New or adjacent symptomatic VCFs occurred in 24/331 (7.2%) (PVP 16/182 vs. BKP 8/149). Posterior instrumentation and fusion for progressive kyphosis during follow-up was required in 17/331 patients (5.1%): 4/129 men (3.1%) and 13/202 women (6.4%). Other events were uncommon: pulmonary embolism 2/331 (PVP, 1; BKP, 1), myocardial infarction 1/331 (0.3%; BKP), hematoma 2/331 (0.6%), transient hemodynamic change 1/331 (0.3%), pneumonia/hypoxia 1/331 (0.3%), and infection 1/331 (0.3%).

## DISCUSSION

Principal findings and clinical meaning. In this single-center, mixed PVP/BKP series of 331 patients, pain improved substantially ( $\approx 5$ -point early VAS decrease), radiographic cement leakage was low (3.9%) with only one symptomatic event, and new/adjacent symptomatic VCFs were infrequent (7.2%). A 5.1% reoperation rate for progressive kyphosis (posterior instrumentation/fusion) provides a meaningful, patient-centered endpoint. These results align with contemporary evidence that vertebral augmentation delivers rapid analgesia with a generally favorable safety profile. The balance between PVP and BKP often reflects anatomy, fracture chronicity, and the need for height restoration (2,8,12-17).

Context within randomized and comparative data. Our early pain trajectory is consistent with randomized controlled trials and meta-analyses showing large, early analgesic effects after augmentation, most notably the BKP FREE program versus non-surgical care, and positive PVP results when acute, edematous fractures are selected (e.g., VERTOS II, VAPOUR). By contrast, the 2009 New England Journal of Medicine sham-controlled trials suggested limited benefit for PVP in mixed-chronicity cohorts; taken together, these data emphasize patient selection and timing rather than a blanket endorsement or rejection of PVP. Head-to-head data suggest broadly similar pain/functional improvements for PVP vs BKP, while BKP tends to yield greater height/kyphosis correction (2,13,14,17).

Radiographic alignment and technique choice. Although our manuscript focuses on clinical outcomes, the access strategy and device selection imply a pragmatic approach: BKP for cases where creating a cavity aids in cement control or height restoration, and PVP when controlled trabecular fill is feasible without cavity preparation. Prior trials and reviews show greater vertebral height restoration and local kyphosis correction with BKP (FREE and subsequent analyses), whereas post-procedure pain tends to be comparable across techniques at short-term follow-up. This supports individualized modality selection, guided by fracture morphology (endplate compliance, intravertebral cleft, posterior wall integrity) (2,8,12,18).

**Cement leakage:** A technique-sensitive endpoint. Our overall 3.9% radiographic leakage rate (PVP, 8/182; BKP, 5/149), with only one symptomatic case, appears lower than pooled estimates (e.g.,  $\approx 20\%$  PVP vs.  $\approx 7\%$  BKP, many asymptomatic) from older meta-analyses (likely reflecting viscosity-timed injection, incremental low-pressure delivery, and cavity creation when cortical defects or clefts were present). Evidence consistently links intradiscal spread,

posterior cortical disruption, low viscosity, and larger injected volumes to higher leakage (and to earlier adjacent fractures), highlighting the importance of stopping rules near the posterior third and avoiding intradiscal migration (13,19,20).

New/adjacent vertebral fractures and biological background. The 7.2% rate of symptomatic new/adjacent fractures in our cohort, is at the lower end of the historical range. Observational data and biomechanical studies suggest that both disease biology (severe osteoporosis, thoracolumbar junction mechanics) and technical factors (intradiscal cement, overcorrection, abrupt stiffness gradients) may influence these events. Notably, intradiscal leakage has been associated with earlier adjacent fractures; rigorous osteoporosis management (antiresorptive or anabolic therapy), attention to cement distribution, and gradual alignment correction remain key mitigations (2,15-17,20).

Reoperation for progressive kyphosis: who is at risk? Our 5.1% reoperation rate (more frequent in women, consistent with the higher osteoporotic burden) underlines that deformity progression can still occur despite initial stabilization particularly in multilevel disease, severe baseline collapse, or when fracture chronicity blunts height recovery. Although high-quality comparative data on post-augmentation fusion are limited, this finding supports longitudinal radiographic monitoring, targeted bracing/rehabilitation, and aggressive bone health optimization. Future work might integrate morphological predictors (cleft, posterior wall breach), cement metrics (viscosity/volume/centroid), and BMD into a practical risk model to anticipate which patients may benefit from earlier deformity control strategies (16,17).

### Study Limitations

This study has several limitations. It was a single-team, retrospective analysis, which may limit the generalizability of the findings. The follow-up period was relatively short, possibly underestimating late complications such as adjacent fractures or progressive kyphosis. In addition, the choice between PVP and BKP was based on surgeon preference rather than randomization, introducing potential selection bias. Future multicenter prospective studies with longer follow-up are needed to validate these results.

## CONCLUSION

In a 331-patient, mixed PVP/BKP experience, augmentation provided rapid and durable pain relief with low symptomatic complication rates and a modest incidence of new fractures; reoperation for progressive kyphosis occurred in

approximately 5%. Together with randomized and meta-analytic data, these findings support selection-driven use of PVP or BKP, prioritizing cement control, avoidance of intradiscal spread, and alignment goals while pairing the procedure with aggressive osteoporosis therapy and structured follow-up to minimize downstream fractures and deformity.

## ETHICS

**Ethics Committee Approval:** Ethical approval was obtained from Bahçeşehir University Non-Interventional Studies Ethics Committee (approval no: 2025-14/08, date: 19.09.2025).

**Informed Consent:** All patients provided written informed consent consistent with local regulations.

## FOOTNOTES

### Authorship Contributions

Surgical and Medical Practices: A.G., A.E., E.Y., S.C., Concept: A.E., E.Y., A.U., S.C., Design: A.G., E.Y., A.U., S.C., Data Collection or Processing: A.E., S.C., Analysis or Interpretation: E.Y., S.C., Literature Search: A.G., S.C., Writing: A.E., S.C.

**Conflict of Interest:** No conflict of interest was declared by the authors.

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