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Research Article

Early catastrophic proximal junctional fracture after spinal instrumentation in geriatric patients

Geriatrik hastalarda spinal enstrümantasyon sonrası erken katastrofik proksimal junksiyonel kırık

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Abstract

Aim: The purpose of this investigation was to evaluate the effectiveness of pedicle screw fixation and bilateral hooks in the prevention of proximal junctional kyphosis (PJK) and proximal junctional proximal junctional insufficiency/failure (PJI) among high-risk elderly patients.

Material and Methods: This retrospective study included 56 high-risk elderly patients who underwent long-segment spinal instrumentation and fusion between 2021 and 2024. Group A consisted of 26 patients who received pedicle screw fixation, while Group B comprised 30 patients who underwent bilateral hook placement during surgery. The primary outcomes were the development of proximal junctional kyphosis (PJK) and proximal junctional failure (PJF). Preoperative and postoperative assessments, including the Visual Analog Scale (VAS), the Oswestry Disability Index (ODI) for functional status, and the 36-Item Short Form Health Survey (SF-36) for quality of life, were retrieved from patient medical records.

Results: PJK occurred in 26.9% of the pedicle screw group (Group A) compared with 6.7% in the bilateral-hook group (Group B), while PJF rates were 19.2% and 3.3%, respectively ($p < 0.05$). Neurologic deficits developed in 11.5% in Group A and 3.3% in Group B ($p = 0.044$). Significant improvements were observed in postoperative VAS, ODI, and SF-36 scores in both groups, with Group B showing better outcomes ($p < 0.001$). Age over 70 years (OR 1.68–2.24), T-score ≤ −2.5 (OR 1.92), number of previous operations (OR 1.64–2.86), an upper-instrumented vertebra at T10 or above (OR 1.78), and pedicle screw fixation (OR 2.84) were independent risk factors for increasing the risk of developing PJK/PJF.

Conclusion: This study indicates that the use of bilateral hooks reduces the risk of proximal junctional kyphosis and proximal junctional fracture in elderly high-risk patients after spinal fusion compared with pedicle screw fixation alone. Bilateral-hook placement was associated with lower complication rates and better clinical outcomes in terms of pain reduction, functional improvement, and return to daily activities.

Keywords: proximal junction insufficiency, proximal junction kyphosis, spine fracture

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Öz

Amaç: Bu araştırmanın amacı, yüksek riskli yaşlı hastalarda proksimal junksiyonel kifoz (PJK) ve proksimal junksiyonel yetmezlik/fraktür (PJF) gelişiminin önlenmesinde pedikül vida fiksasyonu ve bilateral kanca desteğinin etkinliğini değerlendirmekti.

Gereç ve Yöntemler: Bu retrospektif çalışmaya 2021–2024 yılları arasında uzun-segment spinal enstrümantasyon ve füzyon uygulanan 56 yüksek riskli yaşlı hasta dahil edildi. Grup A, pedikül vida fiksasyonu uygulanan 26 hastadan; Grup B ise cerrahi sırasında bilateral kanca yerleştirilmesi uygulanan 30 hastadan oluşmaktaydı. Birincil sonuçlar PJK ve PJF gelişimiydi. Hastaların preoperatif ve postoperatif dönemlerde Görsel Analog Skala (VAS), fonksiyon için Oswestry Engellilik İndeksi (ODI) ve yaşam kalitesi için 36 Maddelik Kısa Form Sağlık Anketi (SF-36); değerlendirmeleri hasta dosyalarından toplandı.

Bulgular: Pedikül vida grubunda (Grup A) PJK %26,9 oranında görülürken, bu oran bilateral-kanca grubunda (Grup B) %6,7 idi. PJF oranları ise sırasıyla %19,2 ve %3,3 olarak saptandı ($p < 0,05$). Nörolojik defisit gelişimi Grup A'da %11,5, Grup B'de %3,3 idi ($p = 0,044$). Her iki grupta da postoperatif VAS, ODI ve SF-36 skorlarında anlamlı iyileşmeler gözlendi; bununla birlikte Grup B daha iyi sonuçlar gösterdi ($p < 0,001$). Yetmiş yaş üstü olmak (OR: 1,68–2,24), T-skorunun ≤ –2,5 olması (OR: 1,92), geçirilmiş operasyon sayısı (OR: 1,64–2,86), üst enstrümante vertebranın T10 veya daha üst seviyede olması (OR: 1,78) ve pedikül vida fiksasyonu (OR: 2,84) PJK/PJF geliştirme riskini artıran faktörlerdi.

Sonuçlar: Bu çalışma, bilateral kanca kullanımının, yalnız pedikül vida fiksasyonuna kıyasla, spinal füzyon sonrası yüksek riskli yaşlı hastalarda PJK ve PJF riskini azalttığını göstermektedir. Bilateral-kanca yerleştirilmesi; ağrının azaltılması, fonksiyonel iyileşme ve günlük aktivitelere dönüş açısından daha düşük komplikasyon oranları ve daha iyi klinik sonuçlar ile ilişkiliydi.

Anahtar Kelimeler: proksimal junksiyonel yetmezlik, proksimal junksiyonel kifoz, spinal kırık

Introduction

Proximal junctional kyphosis (PJK) and proximal junctional insufficiency/failure (PJI) are well-recognized complications after long-segment instrumented fusion for adult spinal deformity and can adversely affect postoperative outcomes and quality of life [1]. PJK is a radiographic deformity occurring at the transition zone between the fused segment and the proximal mobile segment, and it often presents with minimal clinical impact [2]. By contrast, PJI represents the most severe end of the PJK spectrum and is characterized by structural failure at the proximal junction [3]. When PJI occurs, serious damage can develop at the upper junctional region—including vertebral fracture, subluxation at or just above the upper instrumented vertebra, implant failure, or disruption of the posterior ligamentous complex [4].

The pathogenesis of PJK/PJI is multifactorial. Patient-related factors (advanced age, low bone mineral density/osteoporosis, sarcopenia, and systemic comorbidities) interact with surgical and radiographic factors (extent of fusion, construct stiffness, rod material, sagittal alignment targets, and abrupt junctional transitions) to precipitate junctional breakdown [5, 6]. Despite multiple preventive approaches proposed in the literature—including tailoring sagittal correction to age-appropriate targets, judicious selection of uppermost instrumented vertebra (UIV), modulation of construct stiffness, and various junctional protection strategies—junctional complications remain common and clinically important [7-10]. Beyond their impact on individual patients, PJK and PJI impose substantial healthcare burdens by increasing the likelihood of re-interventions and revision surgery [11].

Given the persistently high incidence and clinical significance of junctional complications, there is a continuing need to evaluate simple, reproducible, and effective preventive strategies in high-risk older adults. One such strategy is the use of bilateral hooks at the junctional level to reduce stress concentration and soften the transition between the rigid instrumented construct and the adjacent mobile segments. The central hypothesis of this study is that, in high-risk geriatric patients, adding bilateral hook support to pedicle-screw constructs may mitigate both the development and progression of PJK/PJI and thereby enhance early postoperative clinical outcomes. Therefore, this study aimed to evaluate the effectiveness of pedicle screw and bilateral hook support in the prevention of PJK and PJI among high-risk elderly patients.

Material and Methods

This retrospective cohort study included geriatric patients who underwent long-level spinal instrumentation and

fusion at Eskişehir City Hospital between 2021 and 2024. The protocol was approved by the Ethics Committee of Eskişehir City Hospital (Date: 29.12.2023, No: KU.FR.08.04) and was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki (Brazil revision, 2013). The need for informed consent was waived under the approval of the Local Ethics Committee due to the retrospective design.

Patient Selection

Eligible patients were older than 68 years, at high risk of bone fracture, and had a history of previous spinal surgery. Inclusion criteria: osteoporosis (T-score ≤ −2.0), spinal instability, and previous spinal surgery. Exclusion criteria: malignancy, infection at the previously operated spinal segment, and metabolic bone disease. This study analyzes cases of early PJF after spinal instrumentation in geriatric patients. A total of 56 consecutive patients met the criteria. Group A comprised 26 patients who underwent pedicle screw fixation. Group B comprised 30 patients who underwent bilateral hook placement during surgery. The mean age was 71.6 ± 3.5 years, and 85.7% were female.

Surgical Procedures

Group A received pedicle screw fixation without additional proximal support. Group B received bilateral hooks at the proximal level (Figures 1 and 2). Instrumentation levels and operative techniques were recorded for all patients. All patients were followed for 12 months postoperatively at prespecified time points consistent with routine clinical care.

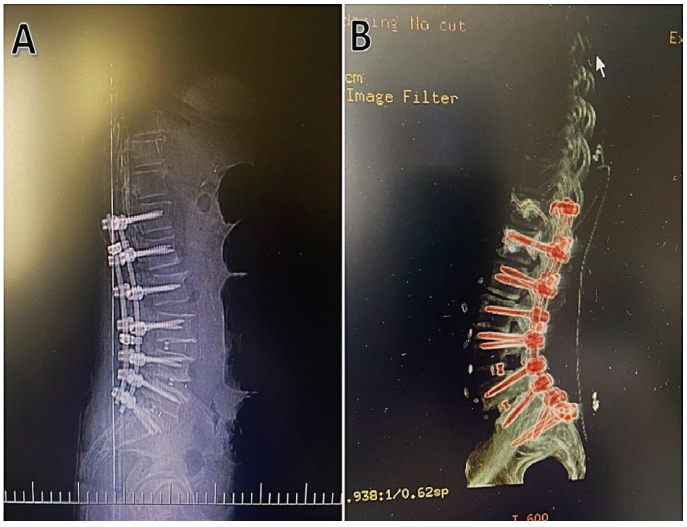

Figure 1. Group A Patient with Only Screw (A); Group B Patient with Hook Support (B).

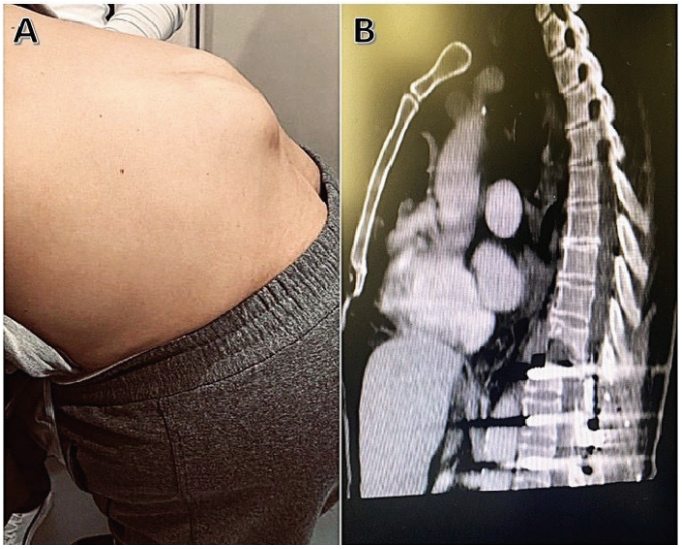

Figure 2. Picture of Physical (A) and CT Appearance of Fracture (B).

Data Collection

Demographic and clinical characteristics, surgical details, and postoperative complications were extracted from institutional records. Patient-reported outcomes were collected using validated instruments: Visual Analog Scale (VAS), Oswestry Disability Index (ODI), and Short Form-36 (SF-36).

Outcomes

Primary observation was the occurrence of early PJF after spinal instrumentation. Secondary observations included PJK, neurological deficit, hardware failure, and changes in VAS, ODI, and SF-36 scores.

Statistical Analysis

In the study, demographic and clinical characteristics of the patients, surgical details, complications and patient outcomes were evaluated with various scales. Data were collected using measurement tools such as VAS, ODI, SF-36. Measurements were performed at certain time intervals in the preoperative and postoperative periods. The data obtained in the study were analyzed with appropriate statistical methods. Comparisons between groups were made with parametric and nonparametric tests such as t-test and chi-square test. Statistical significance level was accepted as $p<0.05$. Odds ratio (OR) and confidence intervals (CI) were calculated and risk factors were analyzed.

Results

The mean age of the patients included in the study was 71.6 ± 3.5 years, with the majority being women (85.7%). The mean body mass index (BMI) was 25.7 ± 2.3 kg/m^2. The mean T-score of the patients was −2.46 ± 0.33. Regarding previous surgeries,

most patients (57.1%) had undergone one prior operation. The smoking rate was 16.1%. There was no statistically significant difference between Group A and Group B in terms of age (p = 0.742), gender (p = 0.856), BMI (p = 0.745), and T-score (p = 0.724). Similarly, there was no significant difference between the groups regarding the number of previous operations (p = 0.912).

Regarding surgical details, instrumentation levels varied significantly between groups (p = 0.038), with T12–S1 being the most common level in both groups (53.8% in Group A and 73.3% in Group B). Cement augmentation and iliac screws were used in 100% of cases in both groups. By study design, Group A utilized only pedicle screws, while Group B employed bilateral hooks (p < 0.001). PJK occurred in 26.9% of Group A compared to 6.7% in Group B (p = 0.042), while PJF occurred in 19.2% of Group A versus 3.3% in Group B (p = 0.048). Neurological deficits developed in 11.5% of Group A patients and 3.3% in Group B (p = 0.044). Hardware failure was observed in 15.4% of Group A compared to 3.3% in Group B (p = 0.039).

In terms of patient outcomes, both groups showed significant postoperative improvements in all measured parameters. VAS back pain scores improved from 7.4 ± 1.2 to 4.6 ± 1.4 in Group A and from 7.3 ± 1.1 to 2.8 ± 1.0 in Group B (p < 0.001). ODI scores improved from 58.6 ± 8.2 to 36.4 ± 9.6 in Group A and from 57.8 ± 7.9 to 24.5 ± 7.8 in Group B (p < 0.001). SF-36 physical component scores showed greater improvement in Group B (from 30.2 ± 5.2 to 48.6 ± 6.2) compared to Group A (from 29.6 ± 5.4 to 42.8 ± 6.8) (p < 0.001). Regarding recovery status, 86.7% of Group B patients achieved excellent/good outcomes compared to 61.5% in Group A (p < 0.001). Similarly, complete return to daily activities was achieved by 86.7% of Group B patients versus 65.4% in Group A (p < 0.001).

Risk factor analysis revealed that age 70–75 years increased the risk of PJK/PJF by 1.68 times (95% CI: 1.12–2.52, p = 0.012), while age >75 years increased it by 2.24 times (95% CI: 1.46–3.44, p = 0.001). A T-score of ≤ −2.5 increased the risk by 1.92 times (95% CI: 1.28–2.88, p = 0.002). The number of previous surgeries showed a progressive increase in risk, with one prior surgery increasing risk by 1.64 times (95% CI: 1.08–2.48, p = 0.018), and three or more surgeries increasing it by 2.86 times (95% CI: 1.74–4.68, p < 0.001). The upper instrumented vertebra at T10 or above increased risk by 1.78 times (95% CI: 1.18–2.68, p = 0.006), and the use of pedicle screws instead of bilateral hooks increased the risk by 2.84 times (95% CI: 1.86–4.34, p < 0.001) (Figure 3).

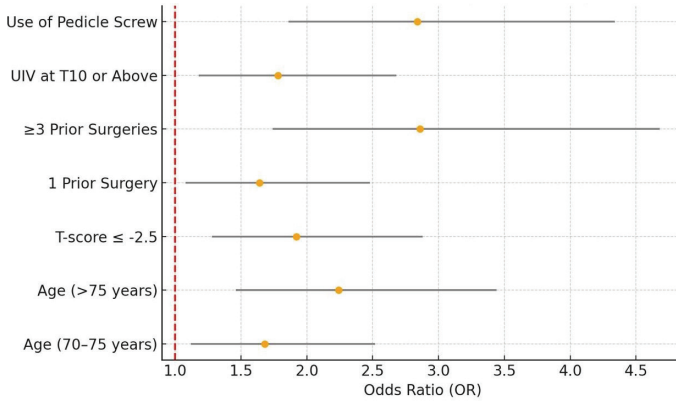

Figure 3. Odds Ratios for Risk Factors Proximal Junctional Kyphosis and Insufficiency.

Discussion

Proximal junctional fracture (PJF) and proximal junctional kyphosis (PJK) are serious complications after spinal instrumentation. In our cohort, PJK occurred in 26.9% of Group A versus 6.7% of Group B, and PJF in 19.2% versus 3.3%, respectively, aligning with reported ranges for PJK (≈5–40%) and PJI (1–20%) [2, 12]. The markedly lower rates in Group B support a protective effect of bilateral hooks, consistent with evidence that hook constructs redistribute proximal junctional loads and reduce PJK/PJF [13]. The higher PJK rate in Group A may reflect postoperative sagittal imbalance and insufficient correction of preoperative positive sagittal malalignment, factors linked to junctional complications [14].

Neurologic deficit developed in 11.5% of Group A versus 3.3% of Group B. This rate in the pedicle-screw cohort is consistent with prior reports for traditional screw-only constructs (≈10–15%), whereas the notably lower incidence in the bilateral-hook cohort suggests a potential neuroprotective effect of this technique. In line with the literature, selection of the upper UIV and the specific surgical strategy are critical determinants of postoperative neurologic complications in the context of PJF [15]. Bilateral hooks may mitigate these events by modulating proximal construct stiffness and redistributing loads at the junctional transition. Comparative evidence also supports the role of adjunctive strategies in reducing neurologic complications. Posterior polyethylene tethers have been reported to lower neurologic deficit risk after long-segment instrumentation and are recommended particularly for high-risk patients [16]. Likewise, multilevel stabilization screws (MLSS) have been associated with reduced neurologic deficits and decreased PJI relative to conventional methods [17]. Taken together, these observations parallel our findings and reinforce

the potential neurological safety advantage of bilateral hook fixation over traditional pedicle screw constructs.

The preventive effect of hook use on PJK and PJI is supported by prior research. Multiple studies report that hooks reduce both PJK and PJF, with lower overall complication rates. For example, the use of TPH has been associated with a significant reduction in PJI and PJF, including a series in which TPH lowered these rates to 0% compared with rates as high as 30% with alternative techniques [18]. The efficacy of hooks is particularly notable in spinal deformity surgery, where they appear advantageous relative to approaches such as vertebroplasty, terminal rod contouring, and ligament augmentation [19]. Comparative evidence also suggests superiority over conventional pedicle screw constructs in selected settings; in adolescent idiopathic scoliosis, for instance, hook-based fixation yielded lower PJI rates than pedicle screws and was therefore favored [20]. Collectively, these findings support hooks as an effective preventive strategy against PJI (and PJF/PJK), especially within posterior spinal fusion procedures.

Risk stratification helps contextualize our findings. Age, low T-score, and the number of prior operations are consistently linked to proximal junctional complications, and our results align with this pattern. Osteoporosis is particularly influential: vertebral fragility related to low T-scores is a major risk factor for postoperative PJI [21], consistent with the low T-scores observed in our cohort and the higher PJI rate in Group A. Additional contributors reported in the literature—higher BMI, poor paravertebral musculature, and pelvic fixation—also predispose to PJI and are relevant to our patient profile [22]. Comparisons with prior studies indicate that our Group B showed more favorable mobilization and overall recovery, paralleling meta-analytic evidence that underscores these risk factors [22]. Achieving and maintaining sagittal balance is likewise critical; inadequate postoperative alignment is associated with higher PJI rates and worse outcomes, as reported by Sakuma et al. [23]. Collectively, these observations support the view that baseline bone quality and modifiable surgical/postoperative factors jointly determine the risk of PJI and PJK.

Our surgical approach yielded PJK and PJI outcomes that differ in magnitude from several prior reports. The literature indicates that both pedicle screws and bilateral hook placement can be effective and durable; however, pedicle screw use at the upper instrumented vertebra is generally associated with a higher risk of PJI, whereas transverse-process hooks appear to mitigate this risk. In a systematic review, Vercoulen et al. reported that transverse-process hooks reduced PJI rates and were associated with lower complication rates than pedicle screws [18]. Biomechanical work by Cammarata et al. similarly showed that substituting transverse-process hooks for pedicle screws at the upper instrumented vertebrae decreased proximal stresses and lowered the likelihood of PJI [24]. These data align with the lower complication profile observed with bilateral hook placement in our cohort and its apparent benefit for PJK prevention. Even so, Solomon et al. concluded that, while hooks can reduce junctional complications, no single construct demonstrates unequivocal superiority across studies [25]. Taken together, the evidence supports the selective use of hook-based constructs—particularly at the proximal level—while emphasizing individualized technique selection based on patient risk and alignment goals.

The major advantage of this study is that it assessed the use of bilateral hooks, which has already been shown to reduce the incidence of PJK and PJF. Such evaluation of patient outcomes using the standardized scales—VAS, ODI, and SF-36—makes this study more robust; however, the small sample size and short follow-up limit these findings. The findings indicate that the use of hooks could be standardized in the management of postoperative complications, especially in older patients. This technique, however, requires further studies to ascertain its effectiveness and support broader use. In the next phase, longer-term follow-up studies with larger patient cohorts, as well as comparative studies of other surgical procedures, should be conducted to help define the optimal strategy.

In conclusion, bilateral hook fixation at the proximal level was associated with fewer proximal junctional complications compared with pedicle screw constructs in a geriatric cohort. These findings support the selective use of hooks as a proximal fixation strategy to mitigate PJK and PJF in high-risk patients.

Ethical Approval

This study was approved by the Ethics Committee of Eskişehir City Hospital (Date: 29.12.2023, No: KU.FR.08.04).

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Conflicts of Interest

Authors declare that they have no conflicts of interest.

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