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# PCL injury following high energy trauma: associated injuries and postoperative complications "insights from a national registry study"

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## Abstract

**Purpose** The posterior cruciate ligament (PCL) is a vital knee stabilizer. While PCL injuries are rare, high-energy traumas can lead to total ruptures, with accompanying injuries requiring surgery. This study aims to investigate the demographics, concomitant injuries, and postoperative complications of patients who underwent PCL reconstruction due to high-energy trauma in a large patient sample.

**Methods** Patients who underwent PCL reconstruction from 2016 to 2022 were retrospectively evaluated using data from a nationwide personal health recording system. Patient demographics, injury mechanisms, associated fractures, soft tissue injuries, and postoperative complications were collected from patient notes, clinical visits, and surgical notes. Individuals with a PCL injury following high-energy trauma (car accident, falls from height, motorcycle accident) with a minimum follow-up of 1 year were included in the study.

**Results** The study included 416 patients with a mean age of 32.4 years. Isolated PCL injuries (n = 97, 23.3%) were observed less frequently than multiple-ligament injuries (n = 319, 76.7%). Most cases were treated with single-stage surgery (86.8%), while staged surgeries were performed in a minority of cases (13.2%). There was no relationship between trauma mechanisms and multiple-ligament involvement, accompanying injuries, or postoperative complications. Surgeries following car accidents were more likely to occur as staged surgeries ($p = 0.014$). Additionally, the complication rates for staged surgeries and younger patients (≤ 18 years) were significantly higher ($p = 0.009$).

**Conclusion** High-energy trauma-induced PCL injuries are often associated with severe concurrent knee injuries with multiple ligament involvement. PCL reconstructions following car accidents are more likely to be staged. These findings highlight the importance of careful consideration in managing these cases to minimize complications, particularly in younger age groups.

**Level of evidence** Level III.

**Keywords** Posterior cruciate ligament, High-energy trauma, PCL reconstruction, High-energy posterior cruciate ligament injury, Staged surgery, Complications

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## Introduction

The posterior cruciate ligament (PCL) is one of the main stabilizer ligaments of the knee, whose function is mainly to avoid posterior translation of the tibia and contribute to the rotational stability of the knee [1–3]. Being the strongest cruciate ligament and covered by the synovium, PCL rupture is infrequently seen, and this ligament possesses more healing potential than the anterior cruciate ligament (ACL) [4]. The general population tolerates mild to moderate and isolated injuries to this ligament [5–8]. On the other hand, sports injuries or high-energy traumas such as motor vehicle accidents can lead to total rupture of the PCL, usually with concomitant multiple-ligament injuries, causing severe posterior/multidirectional instability of the knee and requiring surgical reconstruction [9].

Increasing numbers of publications have highlighted the surgical treatment of PCL injuries in the last two decades, and sports injuries constitute a large percentage of cases in the countries for which such data are available [7, 10, 11]. However, injury patterns vary depending on the prevalence of different lifestyles and types of popular sports in the countries from which the data are obtained. Asian populations are more prone to PCL injuries from motorcycle accidents, while contact sports account for a high percentage of PCL injuries in Western populations [12]. Moreover, the awareness of orthopedic surgeons and the availability of imaging studies, coupled with the increasing incidence of traffic accidents and the number of athletes, have collectively contributed to rising trends in PCL reconstructions compared to previous periods [13]. Considering the long-term protective effects of PCL reconstruction on the menisci and chondral tissue, this number increase is understandable [14, 15]. However, in the existing literature on PCL injuries, few studies to date systematically investigate the features and demographic characteristics of affected patients [16, 17]. Studies focusing on isolated PCL injuries while specifically investigating high-energy traumas in detail are also limited [18].

Specific emphasis was placed on high-energy PCL injuries in this study. Whereas sports injuries often result in isolated ligament avulsions, high-energy traumas pose more significant challenges for orthopedic surgeons due to complicating factors, including concomitant fractures and multiple-ligament injuries, often necessitating staged treatment approaches and being associated with an increased likelihood of complications. This study is believed to be the first to investigate in detail the demographic characteristics and postoperative complications among patients who have undergone PCL reconstruction due to high-energy trauma. A cross-sectional study design with a large patient cohort was adopted to analyze the demographics, concomitant injuries, and postoperative complications of patients with PCL reconstructions attributed to high-energy incidents such as vehicle accidents or falls from heights, ensuring a follow-up period of at least one year. It was hypothesized that PCL injuries caused by high-energy traumas are frequently accompanied by additional injuries and are susceptible to severe complications.

## Materials and methods

This study was conducted according to the declaration of Helsinki and received approval from the Ministry of Health with a waiver of informed consent for retrospective data analysis and the health information privacy law (ID: 95741342-020/27112019). We retrospectively screened the codes for PCL reconstruction (P612850, P612850) (https://skrs.saglik.gov.tr/) from 2016 to 2022 using the 'e-Nabiz' digital personal health record system [19]. The 'e-Nabiz' database contains an extensive collection of health-related information from over 85 million citizens. Mandatory reporting by all hospitals since 2016 ensures that the database includes complete and accurate health records. This newly integrated nationwide personal health record system comprises over 30 services for the treatment, prevention, and promotion of health, as well as the management of the health-related data of individuals. Data within the database are standardized based on national health data standards to ensure consistency. A key feature is its capability to validate data; for example, diagnoses are cross-referenced with prescribed medications to confirm treatment appropriateness, and follow-up data are reviewed to evaluate medical procedure outcomes. The system includes various patient details such as notes, clinic visits, laboratory and imaging test results, diagnostic codes, surgery codes, surgical notes, medical device codes, prescriptions, admission and discharge notes, and many others, which are required to be reported by physicians for reimbursement purposes. Eight hundred forty-two relevant patients were identified, and deidentified documents were assessed for demographics, injury mechanisms, associated injuries, surgical planning for ligamentous knee injuries, and postoperative complications by two authors (S.K. and U.K.). Among those 842 patients, 426 with incomplete records were excluded from the study. A total of 416 patients who underwent PCL reconstruction following high-energy PCL injuries were thus considered—patients with prior knee surgeries and those lost to follow-up before one year were excluded, (Fig. 1).

Patients were categorized according to age groups (0–18 years, 19–40 years, and > 40 years), sex, trauma mechanism, associated fractures, associated soft tissue injuries, whether the surgery was staged, and postoperative complications. Data on associated soft

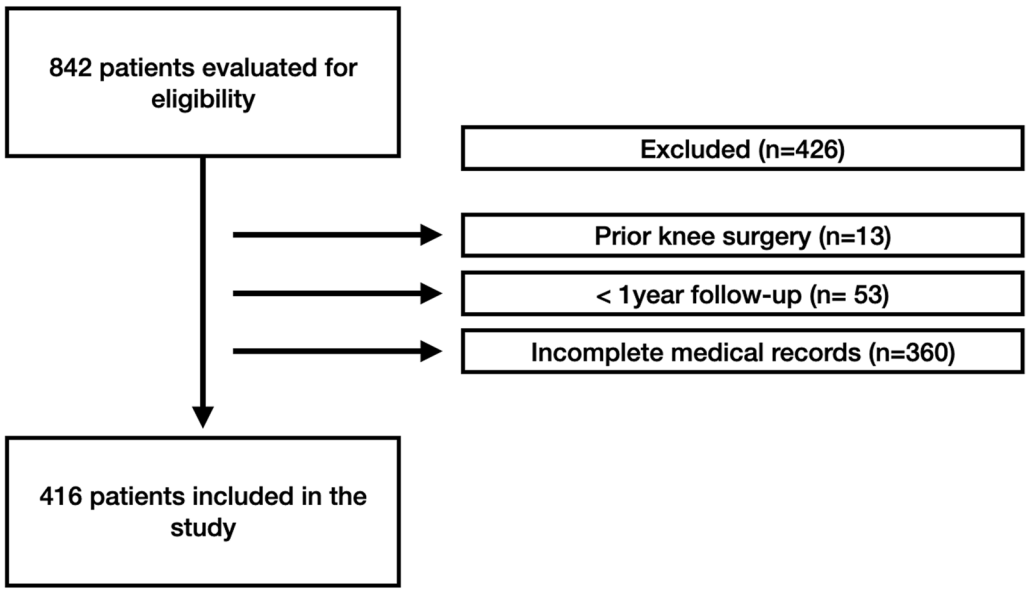


**Fig. 1** Inclusion and exclusion algorithm for patients

tissue injuries, including chondral, ligamentous, and meniscal injuries diagnosed during arthroscopy, were obtained from surgical notes. Multiple ligament injuries involved the medial collateral ligament/posteromedial corner (MCL/PMC), lateral collateral ligament/posterolateral corner (LCL/PLC), or ACL in addition to PCL injury.

Ligamentous injuries were further classified based on the modified Schenck classification as follows: Schenck 1: injury to a single ligament; Schenck 2: injury of both the PCL and ACL; Schenck 3M: injury of the PCL, ACL, and MCL; Schenck 3L: injury of the PCL, ACL, and PLC/LCL; Schenck 4: injury of the PCL, ACL, MCL, and PLC/LCL; Schenck 5: fracture-dislocation [20, 21]. Additionally, to assess the overall severity of injuries, the Injury Severity Score (ISS) was calculated for each patient. The ISS is determined by squaring the highest Abbreviated Injury Scale (AIS) scores from the three most severely affected body regions and summing these squares [22].

### Statistical analysis

The prevalence of associated lesions and complications between single and staged operations and the impacts of age, trauma mechanism, and Schenck classification on complications, staging of the surgery, multiple-ligament injury, and accompanying lesions were statistically compared using Pearson's chi-square test and the Mann–Whitney U test. Statistical analysis was performed using IBM SPSS Statistics 23 (IBM Corp., USA).

## Results

This study included 416 patients, 351 (84.4%) of whom were men while 65 (15.6%) were women. The mean age of the patients was 32.4 (range: 10–64) years. Right-sided PCL injuries (n = 228) were more frequent than left-sided injuries (n = 188) (54.8% vs. 45.2%). The study population comprised 41 patients aged 0–18, 271 patients aged 19–40, and 104 patients aged > 40. The most common mechanism of injury was car accidents, accounting for 70% of the cases (n = 292, 70.2%), followed by falls from heights (n = 69, 16.6%) and motorcycle accidents (n = 55, 13.2%). Associated fractures were observed in 47 patients, with 33 requiring fixation, while 14 were managed conservatively (Table 1). The average ISS for the cohort was 22,5 (range: 4–50), indicating a moderate to severe level of overall trauma among the patients. The most common fractures seen with PCL ruptures were fractures around the knee joint (49%), including 11 tibia (23%), seven femur (14%), and six patella fractures (12%). The most common concomitant soft tissue injuries in the knee were primarily ACL injuries, along with combinations such as ACL injuries concurrent with tears of the medial and lateral menisci or injuries involving the medial and lateral collateral ligaments. Isolated PCL injuries (n = 97, 23.3%) were observed less frequently than multiple-ligament injuries (n = 319, 76.7%). According to the Schenck classification, the distribution of cases was as follows: 97 cases were classified as Schenck 1, 201 were classified as Schenck 2, 41 were classified as Schenck 3 M, 55 were classified as Schenck 3L, 13 were classified as Schenck 4, and 9 were classified as Schenck 5 (Table 2).

**Table 1** Demographic characteristics, numbers of patients by injury mechanism, and associated fractures, injuries and ISS in patients with PCL injuries

| Demographic characteristics | Number (n) | ISS (mean, range) |
|---|---|---|
| Age, years | 32.4 (range: 10–64) | |
| 0–18 | 41 | 18 (4–50) |
| 19–40 | 271 | 22 (4–45) |
| >40 | 104 | 25 (4–48) |
| Male/female, n (%) | 351/65 (84.4%/15.6%) | |
| Male: female ratio | 5.4:1 | |
| Side of the injury, left:right ratio | 228:188 | |
| Mechanism of injury | | |
| Car accidents | 292 (70.2%) | 27 (12–41) |
| Falls from heights | 69 (16.6%) | 19 (4–34) |
| Motorcycle accidents | 55 (13.2%) | 23 (17–42) |
| Associated Injuries | | |
| Head injury (AIS ≥ 2): | 24 | 26 (5–38) |
| Spine injury (AIS ≥ 2): | 6 | 24 (8–45) |
| Chest injury (AIS ≥ 2): | 5 | 23 (7–45) |
| Pelvis injuries (AIS ≥ 2): | 5 | 21 (15–50) |
| Abdominal injury(AIS ≥ 2): | 3 | 20 (4–32) |
| Upper extremity injury (AIS ≥ 2): | 3 | 17 (10–27) |
| Lower extremity injury (AIS ≥ 2): | 52 | 19 (15–35) |
| Knee joint injury | | |
| Tibia | 11 | 21 (4–27) |
| Femur | 8 | 24 (10–30) |
| Patella | 7 | 20 (5–26) |
| Peroneal nerve injury | 6 | 23 (7–28) |

ISS; Injury Severity Score, AIS; Abbreviated Injury Scale

**Table 2** The number of accompanying soft tissue injuries around the knee joint and the distribution of cases according to the Schenck classification

| Associated soft tissue injuries | Number (n) |
|---|---|
| ACL | 170 |
| ACL + MCL | 38 |
| MCL + posteromedial corner (incl. medial meniscus) | 59 |
| LCL + posterolateral corner (incl. lateral meniscus) | 52 |
| Isolated medial meniscus | 5 |
| Isolated lateral meniscus | 3 |
| Chondral lesion | 5 |
| Patellar dislocation | 4 |
| Patellar tendon | 2 |
| Schenck classification | |
| Schenck 1 | 97 |
| Schenck 2 | 201 |
| Schenck 3L | 55 |
| Schenck 3 M | 41 |
| Schenck 4 | 13 |
| Schenck 5 | 9 |

**Table 3** List of the postoperative complications

| Postoperative complications | Number (n) |
|---|---|
| Flexion—extension contracture | 15 |
| Infection (incl. superficial infections) | 10 |
| Chronic pain | 4 |
| Deep vein thrombosis | 3 |
| Persistent instability | 8 |
| Quadriceps atrophy | 2 |
| Pulmonary emboly | 2 |

Fifty patients (12%) experienced complications such as deep vein thrombosis, chronic pain, septic arthritis, surgical site infection and stiff knee (Table 3). The cohort was analyzed according to different age groups regarding complications and prevalence of multiple-ligament injury. It was found that the age group of 0–18 years had more complications compared to the middle age group (19–40 years) and the oldest age group (>40 years) ($p<0.001$). The age group of ≤18 years was also more likely to have multiple ligament injuries (82.9%) compared to the middle age group (75.6%) and the oldest age group (76.9%). However, this difference was not statistically significant (Table 4). Furthermore, according to the Schenck classification, complication rates of different knee dislocation groups did not reveal a statistical difference ($p=0.693$) (Table 5).

Trauma mechanisms were compared with the rate of complications, the necessity of single or staged interventions, isolated versus multiple ligament injuries, and accompanying injuries around the knee (Table 6). There were no statistically significant relationships between trauma mechanisms and complications ($p=0.293$), isolated versus multiple-ligament injuries ($p=0.115$), or accompanying injuries ($p=0.121$). Staged surgery for multiple ligament injuries was required in only 45 cases out of 319 (14.1%). Statistically, surgeries performed for multiple ligament injuries after car accidents were more likely to be staged ($p=0.014$) (Table 6).

Accompanying soft tissue injuries around the knee joint were not associated with an increase in the rate of complications ($p>0.05$). Staged operations were found to be a statistically significant risk factor for an increase in complications ($p=0.09$) (Table 7).

The most frequent graft type used for PCL reconstructions was the hamstring autograft, used in 305 cases, with 293 cases involving the transtibial surgical technique, representing 70.4% (293/416) of all procedures. Bone-patellar tendon-bone graft was used in

**Table 4** Complications and distribution of multiple-ligament and isolated injuries according to age groups. More complications were observed in the youngest age group (*$p < 0.001$)

| | | Age | | | | |
|---|---|---|---|---|---|---|
| | | **0–18** | **19–40** | **> 40** | **Total** | ***p*** |
| Complications | No | 25 | 241 | 100 | 366 | < 0.001 |
| | Yes | 16 | 30 | 4 | 50 | |
| | Total | 41 | 271 | 104 | 416 | |
| Injured ligaments | Isolated | 7 | 66 | 24 | 97 | 0.647 |
| | Multiple ligaments | 34 (82.9%) | 205 (75.6%) | 80 (76.9%) | 319 | |
| | Total | 41 | 271 | 104 | 416 | |

**Table 5** Complications related to Schenck classification. No statistical difference was found between the groups ($p = 0.693$)

| | | Schenck classification | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3L** | **3M** | **4** | **5** | **Total** | ***p*** |
| Complications | No | 84 | 179 | 49 | 37 | 10 | 7 | 366 | 0.693 |
| | Yes | 13 | 22 | 6 | 4 | 3 | 2 | 50 | |
| | Total | 97 | 201 | 55 | 41 | 13 | 9 | 416 | |

**Table 6** Comparisons of complications, staging, multiple-ligament injuries, and accompanying soft tissue injuries in terms of the mechanism of injury. Car accidents were found to be statistically related to staged operations (*$p = 0.014$)

| | | **Falls from heights** | **Motorcycle accidents** | **Car accidents** | **Total** | ***p*** |
|---|---|---|---|---|---|---|
| Complications | No | 48 | 57 | 261 | 366 | 0.293 |
| | Yes | 7 | 12 | 31 | 50 | |
| | Total | 55 | 69 | 292 | 416 | |
| Staged surgery for multiple-ligament injuries | Single Stage | 38 | 51 | 185 | 274 | 0.014 |
| | Two stages | 2 | 3 | 40 | 45 | |
| | Total | 40 | 54 | 225 | 319 | |
| Multiple-ligament injuries | Isolated | 8 | 21 | 68 | 97 | 0.115 |
| | Multiple ligaments | 47 | 48 | 224 | 319 | |
| | Total | 55 | 69 | 292 | 416 | |
| Accompanying injury | No | 6 | 10 | 62 | 78 | 0.121 |
| | Yes | 49 | 59 | 230 | 338 | |
| | Total | 55 | 69 | 292 | 416 | |

68 cases, with 63 of these using the transtibial technique and 5 using the inlay technique. Staged surgeries involved 45 cases, where different graft types such as hamstring (27 cases), bone-patellar tendon-bone (7 cases), quadriceps (5 cases), peronous longus (2 cases) achilles (2 cases) and allografts (2 cases) were used (Table 8).

## Discussion

The most important finding of this study is that PCL injuries caused by high-energy trauma are commonly associated with additional injuries that are prone to severe complications, even in the short term. This study's highest number of cases were classified as Schenck 2 (n = 201, 48.1%), which entails cruciate ligament injury

**Table 7** Comparison of numbers between complications, staging of the surgery, and accompanying soft tissue injuries around the knee joint. Staging of the surgery increased the risk of complications (*$p = 0.009$)

| | Complications | No | Yes | Total | *p* |
|---|---|---|---|---|---|
| Staged surgery for multiple-ligament injuries | No | 241 | 33 | 274 | 0.009 |
| | Yes | 33 | 12 | 45 | |
| | Total | 274 | 45 | 319 | |
| Accompanying soft tissue injuries | No | 69 | 9 | 78 | 0.713 |
| | Yes | 297 | 41 | 338 | |
| | Total | 366 | 50 | 416 | |

of the knee. The most common complication was stiffness of the knee. The majority of PCL injuries and associated injuries were treated via single-stage surgery. Car accidents were more likely to lead to two-stage surgeries when the injuries involved ligaments other than the PCL, indicating the complexity of such injuries. Younger age and staged operations showed trends toward increased complications.

Although PCL injuries are less common than ACL injuries, they are often involved in high-energy ligament injuries to the knee [6, 23, 24]. Mild to moderate PCL injuries can usually be treated without surgery, but in severe cases or cases involving significant knee instability, surgery may be necessary [17]. However, more research has yet to be conducted on high-energy PCL injuries, and this study aimed to fill that gap by investigating associated injuries and complications with a large number of patients over a sufficient follow-up period [9, 10, 17]. Due to our country's high population and traffic accident numbers, the primary aim was to obtain numerically valuable information about high-energy PCL injuries from national registry data.

One of the key findings of this study was that high-energy PCL injuries had a complication rate of 12%. Additionally, there was an 11.3% incidence of associated fractures in acute trauma settings. In a study by Salzler et al. utilizing the American Board of Orthopaedic Surgery database, the complication rates of PCL reconstruction were reported to be as high as 20% [25]. However, that study did not investigate the complications in a detailed manner. The complication rates observed in this study were similar to those found in patients with multiple-ligament injuries, given the association of high-energy PCL injuries with a heightened incidence of multiple-ligament injuries [26]. Moreover, complications arising from the fixation of associated fractures were not examined in this study, potentially contributing to an underestimation of the overall complication rate.

Male patients were approximately five times more likely to suffer from PCL injuries, as also evidenced by various studies that consistently reported similar results, suggesting that high-energy traumas are often associated with activities more commonly undertaken by male individuals [9, 12, 17, 18]. Pediatric PCL reconstructions in individuals under the age of 15 years were notably rare (n = 4), precluding a statistical comparison or in-depth evaluation for that specific age group. However, within our cohort's age group of ≤ 18 years, a propensity for complications was observed ($p < 0.001$). It was surprising that complication rates decreased as the age groups increased. We speculated that this trend could be linked to the more complex nature of injuries with higher energy levels at younger ages in this cohort. However, recent research has indicated the opposite trend in the general population [21]. The slight increase in multiple-ligament injuries in the age group of ≤ 18 years might have affected the complication rate in this group.

**Table 8** Graft types, surgical staging and techniques used in PCL reconstruction

| Graft type | Surgical technique | Single-stage surgery | Staged surgery | Total |
|---|---|---|---|---|
| Hamstring autograft | Transtibial | 268 (72.2%) | 25 (55.6%) | 293 |
| | Inlay | 10 (2.7%) | 2 (4.4%) | 12 |
| Bone-patellar tendon-bone autograft | Transtibial | 57 (15.4%) | 6 (13.3%) | 63 |
| | Inlay | 4 (1.1%) | 1 (2.2%) | 5 |
| Quadriceps autograft | Transtibial | 15 (4.0%) | 5 (11.1%) | 20 |
| | Inlay | 0 (0%) | 0 (0%) | 0 |
| Peroneus longus autograft | Transtibial | 6 (1.6%) | 2 (4.4%) | 8 |
| | Inlay | 1 (0.3%) | 0 (0%) | 1 |
| Achilles tendon autograft | Transtibial | 8 (2.2%) | 2 (4.4%) | 10 |
| | Inlay | 2 (0.5%) | 0 (0%) | 2 |
| Allograft | Transtibial | 0 (0%) | 2 (4.4%) | 2 |
| | Inlay | 0 (0%) | 0 (0%) | 0 |
| Total | | 371 (100%) | 45 (100%) | 416 |

The most common injury mechanism was car accidents (70.2%), followed by falls from heights (16.6%) and motorcycle accidents (13.2%). The rates align with various epidemiological studies concerning car accidents [12]. Moreover, in densely populated regions, transportation-related accidents are prevalent. In certain Asian countries, motorcycle accidents constitute the majority of vehicle accident-related PCL injuries, with studies highlighting an increased incidence of isolated PCL injuries with motorcycles due to direct knee-ground contact [12]. While motorcycle use is not as common in our country as in Asian countries, except for the southern regions, car accidents constituted the primary source of high-energy traumas in this study, as in Western countries [24, 27, 28].

High-energy injury to the knee usually results in injuries to multiple ligaments besides the PCL. ACL injury was the most common accompanying injury (n = 170, 40.1%) in this cohort, as expected and as stated in similar publications. The ACL is seen as the most common accompanying ligament injury in cases of PCL injuries. Owesen et al. found at least one concomitant ligament injury in nearly two-thirds of operated PCL cases [10]. In another study by Caldas et al., two or more ligaments were involved in 85.9% of cases, including posteromedial and posterolateral corner injuries [18]. The high rate of multiple-ligament injuries in their high-energy PCL injury series was consistent with our study, as 75.7% of our patients had more than one ligament involved in their injuries. Although this study did not show an increase in the complication rates of the patients with multiple ligament injuries, Tucker et al. found an increased rate of complications in patients with multiple reconstructed ligaments compared to isolated PCL injuries. However, their cohort consisted of a military population that differed from the general population with higher-energy injuries and higher demands [29]. There is ongoing controversy about the definition of low- and high-energy injuries. Some authors have argued that even sports-related PCL injuries should be presented as multiple-ligament injuries. However, current reviews acknowledged the lower-energy nature of sports injuries and their predisposition to isolated PCL damage compared to high-velocity vehicle accidents or falls from heights [11, 30–32].

Fractures are one of the main factors that make treatment more complex and increase the risk of morbidity. As expected, the most common fractures were observed around the knee joint in this study. Thirty-one of 43 fractures needed operative fixation, but we did not provide detailed statistics because some occurred in anatomical regions unrelated to the PCL, such as pelvic girdle, phalanx, or talus fractures. However, 26 fractures, including bones such as the tibial plateau, distal femur, and patella, were located near the knee joint. The frequency of associated fractures in cases of PCL injury was described by Caldas et al. with a rate of 20.5%, nearly twice the rate of our cohort but a small number of patients [18]. Complications due to fracture treatment were not accounted for in this study.

The high-energy nature of the injuries was also reflected in their distribution according to the Schenck classification. The highest number of cases were classified as Schenck 2 (n = 201, 48.1%), which involves cruciate ligament injury of the knee. A significant number of more complex injuries also reflected the higher classes defined as Schenck 3M (n = 45 10.8%), 3L (n = 60 14.4%), and 4 (n = 13, 3.1%). Although some studies described higher complication rates for Schenck classes 3 and 4 [33], we did not find a statistical difference in complication rates between these groups ($p = 0.693$).

Similarly, comparing the mechanism of injury in terms of complication numbers did not reveal a statistical difference ($p = 0.293$). We did not observe compartment syndrome or vascular injury during or after the operations, but two patients admitted with knee dislocation had vascular injuries that required vascular repair, and they recovered without complications postoperatively. It was found that PCL operations performed for multiple-ligament injuries due to car accidents were more likely to have staged surgeries than those due to other causes ($p = 0.014$). This result seems logical as car accident victims usually present with more complicated injuries compared to the isolated ligament injuries caused by motorcycles [12]. The present study also showed an increase in complications with multi-stage operations in the group with multiple-ligament injuries, as expected ($p = 0.009$), which parallels the findings of previous studies as the complex and lengthy surgical procedures of patients with multiple-ligament injuries are reflected in an increase in complication rates [34].

In our study, the transtibial technique was predominantly used for PCL reconstruction. However, the tibial inlay technique is also a viable option [35, 36]. This technique allows for a direct approach to the tibial insertion of the PCL and can be particularly advantageous in specific clinical scenarios. Both the transtibial and tibial inlay techniques have been shown to produce equivalent results, supporting the choice of technique based on the surgeon's preference and the patient's specific anatomical and injury characteristics [35].

In our cohort, autografts were predominantly used for PCL reconstructions, with allografts used less frequently. This reflects findings from a systematic review showing no significant differences in outcomes between graft types [37]. The preference for autografts often stems

from their availability, cost-effectiveness and fewer concerns about structural integrity after sterilization. However, allografts remain a viable option, particularly when reducing donor site morbidity or opting for less invasive approaches [37, 38]. Notably, no synthetic grafts like the Ligament Advanced Reinforcement System (LARS) synthetic graft were recorded in our registry data. LARS is known for potentially providing immediate stability with lower rates of failure and synovitis, although long-term data on its use in isolated PCL reconstructions remain sparse [38].

In our registry data, consistent findings from recent systematic reviews, the most commonly utilized grafts for PCL reconstructions were the hamstring and patellar tendon autografts [39]. These grafts are preferred due to their strong performance in terms of patient-reported outcomes and joint stability, aligning with global trends that recognize their efficacy and reliability for PCL reconstruction [39].

This study has limitations primarily due to its retrospective nature. The data were obtained from a national digital registry database, which is comprehensive in its radiological reports and operational notes but does not provide any patient feedback regarding clinical outcome scores. Incomplete data on fracture classification, graft types, and revision rates constitute a notable limitation of the study. Additionally, this study predominantly evaluated patients likely to benefit from PCL surgery, potentially limiting generalizability to those severely injured or unfit for surgery. Another weakness of the study was the lack of long-term follow-up, which limited further evaluation of the effects of complications on arthritis and revision rates.

## Conclusion

In summary, this registry-based study revealed that PCL injuries resulting from high-energy trauma frequently coincide with additional knee injuries, leading to a considerable complication risk, particularly knee stiffness, even in the short term. Cruciate ligament injuries, most commonly Schenck class 2, predominate this patient group. The majority were managed with single-stage surgery, although two-stage surgeries were more prevalent following car accidents, reflecting the injury severity. A trend towards higher complication rates was noted in younger patients and those undergoing staged surgeries. Further research is needed to explore the impact of complications on functional outcomes, long-term complications, and refined treatment strategies.

### Abbreviations

PCL Posterior cruciate ligament
ACL Anterior cruciate ligament
MCL Medial collateral ligament
PMC Posteromedial corner
LCL Lateral collateral ligament
PLC Posterolateral corner

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None.

### Author contributions

All authors contributed to the study's conception and design. Data collection and analysis were performed by S.K, M.K, and U.K. The first draft of the manuscript was written by M.K, I.B, U.O, S.B and all authors commented on the versions of the manuscript. I.B and U.O contributed to the interpretation of the data and planning of the research. S.K, U.K and I.B participated in the reviewing and editing of the manuscript before submission. All authors read and approved the final manuscript.

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### Availability of data and materials

Due to the nature of the research, supporting data are not available. No datasets were generated or analysed during the current study.

### Ethics approval and consent to participate

The study was conducted according to the Declaration of Helsinki and received approval from the Turkish Ministry of Health with a waiver of informed consent for retrospective data analysis and the health information privacy law (ID: 95741342-020/27112019). Patients gave written informed consent for participation in the study.

### Consent for publication

Patients gave written informed consent for the publication of the study.

### Competing interests

The authors declare no conflict of interest.

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