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REVIEW

Knee-Spanning External Fixation in the Management of Knee Dislocations and Multiligamentous Knee Injuries: A Narrative Review

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Abstract: Knee dislocations (KD) and multiligamentous knee injuries (MLKI) are challenging injuries to manage due to the high incidence of associated neurovascular compromise, extensive peri-articular soft-tissue trauma, and long-term functional deficits. Knee-spanning external fixation (KSEF) is occasionally utilized in the acute management of these injuries with the aim of maintaining alignment, protecting vascular repairs, allowing soft-tissue recovery prior to definitive treatment, and protecting freshly reconstructed or repaired ligaments. Despite its use in 5% of MLKIs and up to 50% of KDs, the clinical indications, outcomes, and complications associated with KSEF in the setting of KD/MLKI remain incompletely defined. Furthermore, KD/MLKI treatment algorithms incorporating decision-making related to KSEF application are limited both institutionally and within the literature. Thus, the purpose of this study was to consolidate the existing evidence related to the use of KSEF in the setting of KD/MLKI to support clinical decision-making and identify avenues for future investigation. Following a narrative review of the literature, the identified indications for KSEF in the setting of KD/MLKI were vascular injury, knee fracture-dislocation, extensive soft-tissue injury, persistent instability following reduction, open KDs, and when bracing is not feasible due to patient factors such as morbid obesity. Both rigid and hinged KSEF constructs have been described, with hinged fixators potentially permitting early motion while providing joint stability. Reported complications of KSEF include arthrofibrosis, infection, heterotopic ossification, and compartment syndrome, though available data are primarily retrospective and heterogeneous. Other topics that have been addressed in the literature include biomechanics, cost, magnetic resonance imaging (MRI) compatibility, and psychological impact. However, further research is needed to clarify its specific role, define standardized indications, and compare outcomes with non-invasive or alternative fixation and immobilization strategies.

Plain Language Summary: Knee dislocations and multiple ligament knee injuries are serious injuries that can cause damage to blood vessels, nerves, and soft tissues around the knee, leading to long-term challenges with movement. Doctors sometimes use a device called a knee-spanning external fixator to treat these injuries, which is a metal frame that surgeons place outside of the leg to hold the knee stable This article summarizes what doctors and researchers currently know about knee-spanning external fixators, including their risks and benefits, and explains why more research is needed to guide treatment decisions related to the use of these devices in the management of severe knee injuries. This device is mainly used when the knee is too unstable for a brace, when there is a blood vessel injury, when the skin around the knee is severely damaged, and when the patient has multiple other injuries that need to be managed before their knee injury. While knee-spanning external fixators can help protect the knee and allow it to heal, they also carry several risks like stiffness, infections where the pins enter the skin, unwanted bone growth in the knee, and excessive pressure build-up within the leg. There are also psychological and cost-related concerns associated with the use of these devices. Despite being used frequently, doctors and researchers have not reached a clear agreement about exactly when to use or avoid these devices.

Keywords: multiligament knee injury, knee dislocation, external fixation, external fixator, knee-spanning external fixator, polytrauma

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Introduction

Multiligamentous knee injuries (MLKI) are defined as injury to two or more of the major knee ligaments comprising the anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), posteromedial corner (PMC) (including the medial collateral ligament (MCL)) and posterolateral corner (PLC) (including the lateral (fibular) collateral ligament) (Table 1). Knee dislocations (KD), which are not to be equated with MLKI unless a true tibiofemoral dislocation is confirmed, are defined as total disruption of the tibiofemoral joint verified clinically or radiographically (Table 2).[1,2] These injuries are often associated with substantial injury to other musculoskeletal and neurovascular structures of the knee and therefore pose significant challenges for the healthcare system.[3,4] Patients can experience significant deterioration of clinical outcomes over time, particularly when the PCL is involved.[5] Out of 11 million orthopedic injuries from 2004–2009, Arom et al identified 8050 KDs, representing an incidence of 0.072 events per 100 patient-years.[6] Around 28–37% of patients with KD/MLKI require a second knee surgery, with readmission more likely in patients with a documented KD.[7,8] Furthermore, KDs are associated with concomitant vascular injury in up to 38% of cases, which is potentially limb-threatening.[9]

Compared to non-dislocated MLKI, KDs are much more likely to be treated with knee-spanning external fixation (KSEF) (Figure 1).[10] This temporary immobilization technique, which can be in the form of a rigid or hinged construct, is utilized in approximately 5% of MLKIs but up to 50% of KDs, which increases to 72% when vascular injury is

Table 1 Anatomic Classification of Multiple Ligament Knee Injuries[3]

MLKI 1–AM	Complete tear of the ACL with complete tear of the sMCL and/or PMC
MLKI 1–AL	Complete tear of the ACL with complete tear of the LCL and/or PLC
MLKI 1–AML	Complete tear of the ACL with complete tear of the sMCL and/or PMC and the LCL and/or PLC
MLKI 1–PM	Complete tear of the PCL with complete tear of the sMCL and/or PMC
MLKI 1–PL	Complete tear of the PCL with complete tear of the LCL and/or PLC
MLKI 1–PML	Complete tear of the PCL with complete tear of the sMCL and/or PMC and the LCL and/or PLC
MLKI 2	Complete tears of the ACL and PCL without injury to the sMCL, PMC, LCL, or PLC
MLKI 3–M	Complete tears of the ACL and PCL with complete tear of the sMCL and/or PMC
MLKI 3–L	Complete tears of the ACL and PCL with complete tear of the LCL and/or PLC
MLKI 4	Complete tears of the ACL, PCL, sMCL and/or PMC, and LCL and/or PLC

Abbreviations: MLKI, multiligamentous knee injury; ACL, anterior cruciate ligament; sMCL, superficial medial collateral ligament; LCL, lateral collateral ligament; PLC, posterolateral corner; sMCL, superficial medial collateral ligament; PMC, posteromedial corner.

Table 2 Schenck Classification Criteria for Knee Dislocations

KD I KD II	Dislocation including disruption of one cruciate ligament (ACL or PCL) Dislocation including disruption of both cruciate ligaments only (ACL and PCL)
KD III	Dislocation including disruption of both cruciate ligaments (ACL and PCL) and either collateral ligament (MCL or LCL)
KD III-M	Dislocation including disruption of both cruciate ligaments (ACL and PCL) and the MCL
KD III-L	Dislocation including disruption of both cruciate ligaments (ACL and PCL) and the LCL
KD IV	Dislocation including disruption to both cruciate ligaments (ACL and PCL) and both collateral ligaments (MCL and LCL)
KD V	Fracture-dislocation

Abbreviations: MLKI, multiligamentous knee injury; ACL, anterior cruciate ligament; PCL, posterior cruciate ligament; LCL, lateral collateral ligament; MCL, medial collateral ligament.

Figure 1 Anteriorly placed knee-spanning external fixator for an open knee dislocation.

present.[9–11] Knee-spanning external fixation, which aims to maintain joint length and alignment while supporting soft-tissue healing, is applied across various fracture and soft-tissue pathologies of the knee. Typically, the decision to use KSEF depends on injury severity, the need to manage existing or potential complications, and the evaluation of knee instability.[12–17] KSEF may also be applied due to practical considerations related to patient characteristics such as morbid obesity, eligibility for surgery, anticipated non-adherence to bracing protocols, or polytrauma.[18] However, the selective application of pre- and postoperative KSEF represents a significant controversy in the management of KD/MLKI, as KSEF is also associated with several postoperative complications.[19–21]

Despite the existence of KD/MLKI treatment algorithms that incorporate KSEF, their application in clinical practice remains inconsistent. This variability is likely due to the absence of standardized, evidence-based application criteria. The result is that KSEF may be overutilized in stable injuries or underutilized in scenarios where it could be limb-saving. Thus, the purpose of this narrative review was to clarify the role of KSEF in existing KD/MLKI treatment algorithms. We review the published indications for KSEF, compare how they are applied across studies, highlight key controversies, and describe the spectrum of reported complications. The findings provide new insight by synthesizing the literature into a clearer framework to guide clinical decision-making and future research on the use of KSEF for the treatment of KD/MLKI.

Biomechanics

The primary biomechanical goal of external fixation in the trauma setting is stability restoration. KSEF can neutralize varus-valgus, shear, and torsional loads while preserving limb length, assist in resolution of soft-tissue edema, and protect reconstructed ligaments during early rehabilitation.[22,23] Thus, the stability of the mechanical construct largely determines whether the reduction is maintained and/or grafts are protected. KSEF devices are typically constructed using two femoral pins placed anterior or anterolateral and two tibial pins connected by rods/bars, with the knee in full extension to slight flexion (20–30 degrees).[24] Stability of KSEF constructs can be enhanced by increasing the pin diameter, number of pins, and distance between pins and bars, as well as reducing the pin-to-fracture and bar-to-bone distances.[24–27] Multiplanar configurations can further enhance rigidity.[23,28] Several configurations have been assessed biomechanically to optimize stiffness (Figure 2). Mercer et al demonstrated that constructs utilizing anterolateral femoral pin placement coupled with dual connecting rods provided superior stiffness in varus, valgus, and anterior-posterior shear when compared to single monotube or anterior pin placements.[22] Similarly, Desai et al found that using pin-to-bar clamps with two crossbars significantly increased stiffness compared to multipin clamps or single crossbar configurations.[29]

In addition to rigid KSEF constructs, hinged KSEF devices have been increasingly recognized for their ability to permit controlled knee motion postoperatively, thereby minimizing joint stiffness while protecting ligament repairs.[31] Hinged external fixators typically consist of two rigid segments connected via a hinge joint, permitting primarily flexion-extension movements (Figure 3). Biomechanical studies highlight their capacity to reduce stress on ligament reconstructions and stabilize anteroposterior translation post-operatively, with minimal adverse loading of periarticular structures.[32,33] Fitzpatrick et al demonstrated that hinged KSEF devices significantly reduce tibiofemoral translation in cruciate-deficient knees and decrease cruciate ligament strain in intact or reconstructed knees, indicating their utility in KD/MLKI. However, proper alignment and precise axis placement of hinges are critical for avoiding abnormal loading patterns on the knee joint. Hinge axis alignment is typically manually identified via radiographic landmarks, which requires careful technique to prevent misalignment and potential kinematic complications.[33,34] For cases where early controlled knee motion is desirable, hinged KSEF devices offer the advantage of balancing joint stability and mobility, which may be particularly useful following ligament reconstruction.[31] Proper surgical technique and appropriate construct selection can significantly enhance clinical outcomes in managing KDs and MLKIs.

History and Rationale

Traumatic KD/MLKI has long been recognized as a limb-threatening emergency, primarily due to the high risk of popliteal artery disruption, as a missed vascular injury can be catastrophic.[35] Early reports document alarmingly high amputation rates of up 57%.[36] Management strategies have evolved substantially over time and require a careful approach to evaluation and treatment to balance the dichotomous demands of stability and mobility. Until the 1970s, nonsurgical management with closed reduction followed by prolonged cast immobilization was common, with inconsistent outcomes.[37] As surgical techniques and postoperative care improved, surgeons began to favor operative treatment,

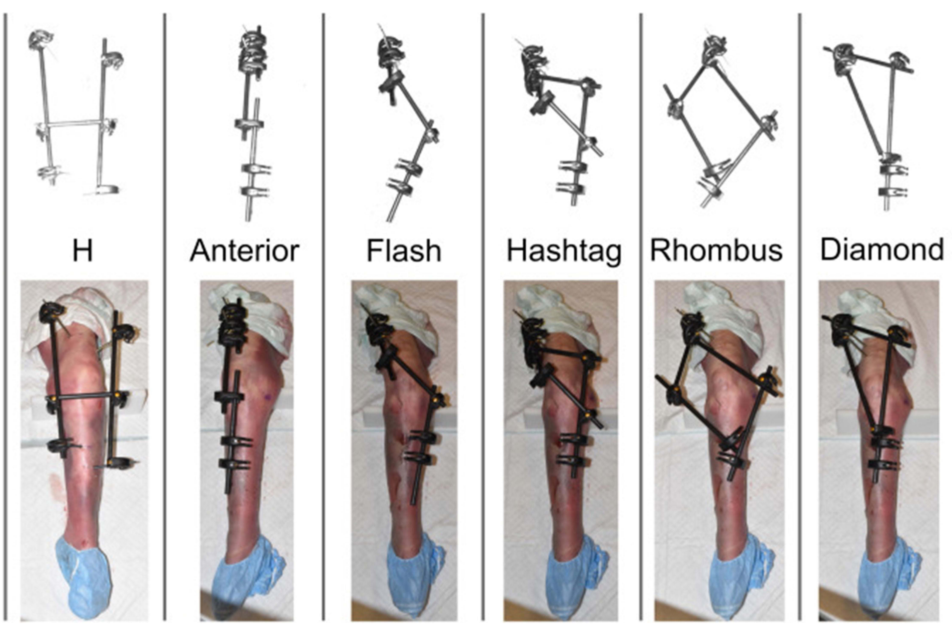

Figure 2 Rigid knee-spanning external fixator construct variations. Reproduced from Morandi MM, Simoncini A, Hays C et al. Optimal configuration for stability and magnetic resonance imaging quality in temporary external fixation of tibial plateau fractures. Orthop Traumatol Surg Res. 2020;106(7):1405–1412. doi:10.1016/j.otsr.2019.12.025,[30] with permission from Elsevier.

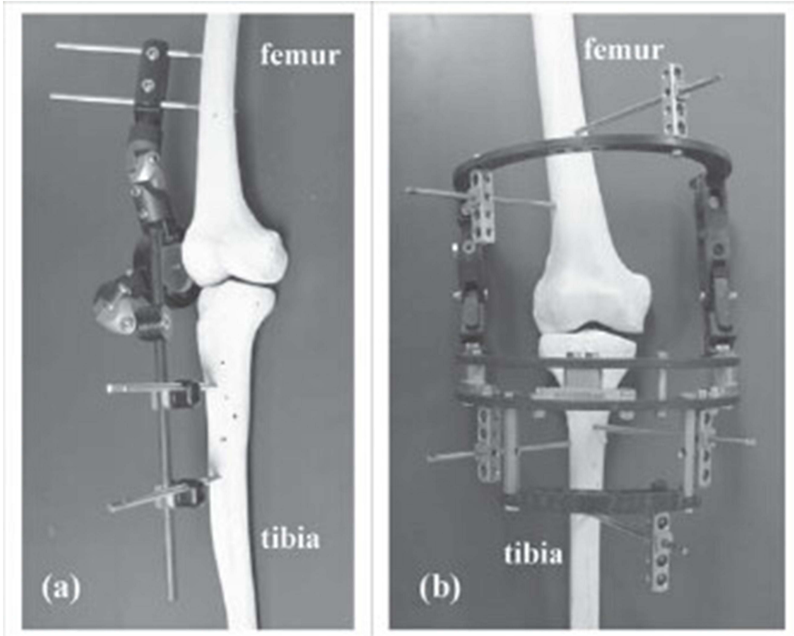

Figure 3 Hinged knee-spanning external fixator constructs demonstrating (**a**) unilateral assembly and (**b**) compass knee hinge. Reproduced from Fitzpatrick DC, Sommers MB, Kam BC, Marsh JL, Bottlang M. Knee stability after articulated external fixation. Am J Sports Med. 2005;33(11):1735–1741. doi:10.1177/0363546505275132,[32] with permission from SAGE Publications.

which can be early or delayed and may include temporizing KSEF.[17,38,39] While surgical timing has been investigated extensively, there remains no consensus on the optimal strategy, including KSEF use, as systematic reviews have yielded mixed results for MLKI[40–47] and KD.[48] This is likely due to the wide range of injury patterns, severity levels, and patient factors, necessitating a tailored approach for each individual scenario. Factors that influence the timing of surgery include vascular injuries, fractures, irreducible dislocations, open injuries, surrounding soft-tissue condition, extensor mechanism disruption, stability of the reduction, head trauma, and visceral injuries.[49]

A staged protocol that involves immediate temporizing KSEF followed by delayed (2–3 weeks) multiligament reconstruction, achieving satisfactory range of motion (ROM) and functional outcomes, was described by Levy et al.[17] This work emphasized the idea that temporizing KSEF can improve limb salvage and overall outcomes following KD/MLKI. In the staged/delayed scenario, temporizing KSEF aims to provide immediate mechanical stability for severely unstable knees that cannot maintain joint reduction through bracing alone, thereby protecting the integrity of neurovascular structures. By delaying definitive ligamentous repair/reconstruction, this approach allows soft-tissue recovery, inflammation reduction, and resolution of any concurrent traumatic injuries in the case of a polytraumatized patient. Thus, the delayed/staged approach with immediate temporizing KSEF aims to balance the urgency of addressing ligament injuries against the practical constraints posed by severe soft-tissue and/or systemic injuries. This is compared to early, single-stage reconstruction without the use of temporizing KSEF, which offers the theoretical advantages of decreased cost, decreased risk of osteoarthritis, and decreased risk of altered knee biomechanics and subsequent meniscal and cartilage damage.[50–54]

As for hinged KSEF, several authors have described its use in various scenarios, primarily for postoperative stabilization and graft protection following acute and chronic KD.[55–60] Hinged KSEF has also been described in the setting of acute fracture-dislocation,[61] recurrent tibiofemoral subluxation,[62] extensor mechanism disruption,[63,64] and status-post extensive capsular release and ligament reconstruction for chronic, fixed KDs.[65–67]

Treatment Algorithms

While there is no universal KD/MLKI treatment algorithm, several authors have described algorithms that incorporate the use of temporizing KSEF.[16,17,68,69] The staged protocol described by Levy et al begins with immediate vascular assessment, followed by temporizing KSEF if there is vascular injury, gross instability after reduction, open dislocation, or an inability to safely mobilize the patient in a brace (Figure 4). Definitive ligament reconstruction is subsequently performed after soft-tissue recovery, typically 3–6 weeks post-injury, with simultaneous repair of all affected ligaments.

Maslaris et al describe a similar systematic algorithm emphasizing an initial rapid vascular assessment and stabilization guided by damage-control orthopedics (Figure 5).[16] Immediate joint reduction is followed by neurovascular examination via ankle-brachial indices (ABI). Temporizing KSEF is applied if there is vascular injury, open injury, compartment syndrome, fracture-dislocation, persistent instability in a brace or other closed means, or polytrauma.

Indications

While KSEF remains a critical intervention for managing KD and MLKI, the indications remain poorly standardized within the literature. Commonly recognized indications include vascular injury, knee fracture-dislocation, persistent instability, open dislocation, severe soft-tissue injury, and specific patient characteristics such as morbid obesity.[9,14–17,70] Vascular injuries are particularly emphasized, with KSEF being utilized largely to prevent redislocation, protect vascular repairs, monitor and manage fasciotomy sites, and enable continued assessment of soft-tissue swelling.[9,17] Likewise, complex fracture-dislocations of the distal femur or tibial plateau, irreducible or redislocating KDs, and chronically subluxated joints are repeatedly listed as absolute indications because they require rigid alignment control prior to

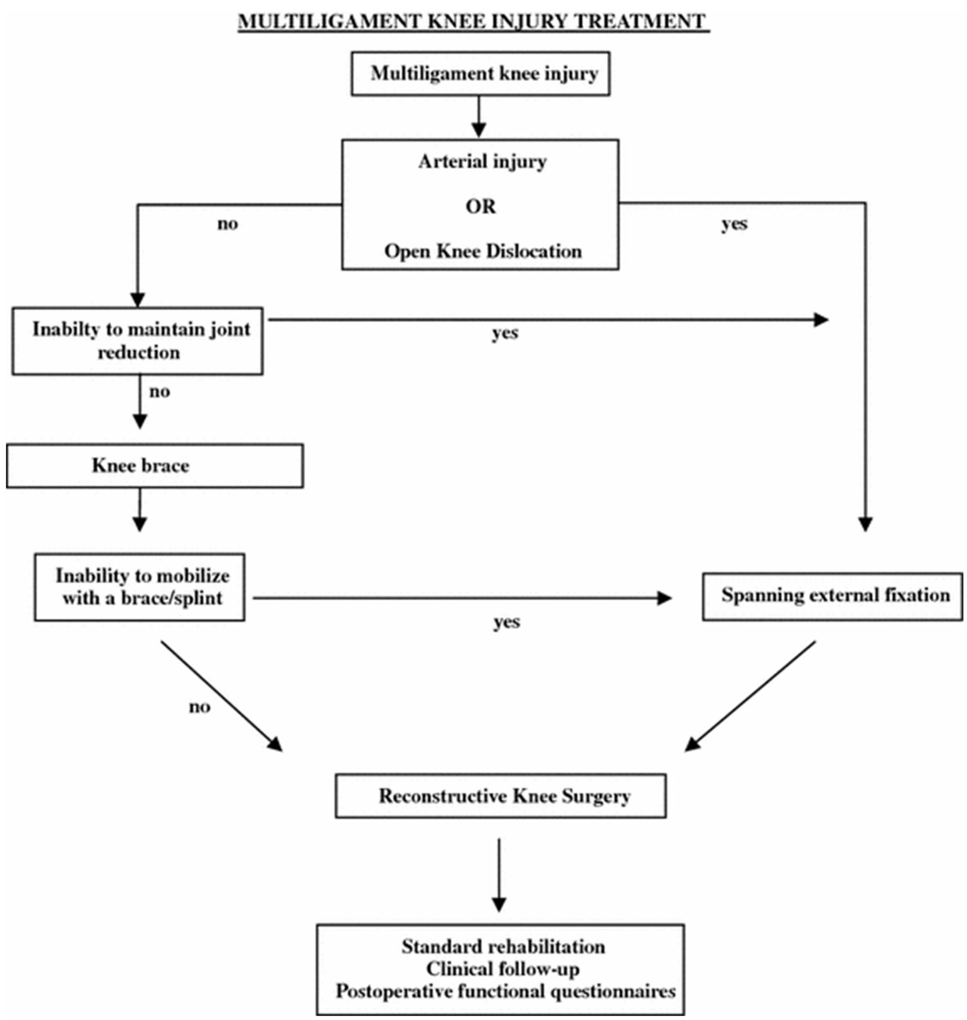

Figure 4 Multiligament knee injury treatment algorithm with temporizing knee-spanning external fixation. Reproduced from Levy BA, Krych AJ, Shah JP, Morgan JA, Stuart MJ. Staged protocol for initial management of the dislocated knee. Knee Surg Sports Traumatol Arthrosc. 2010;18(12):1630–1637. doi:10.1007/s00167-010-1209-y,[17] with permission from John Wiley & Sons. © 2010 John Wiley & Sons, Inc. All rights reserved.

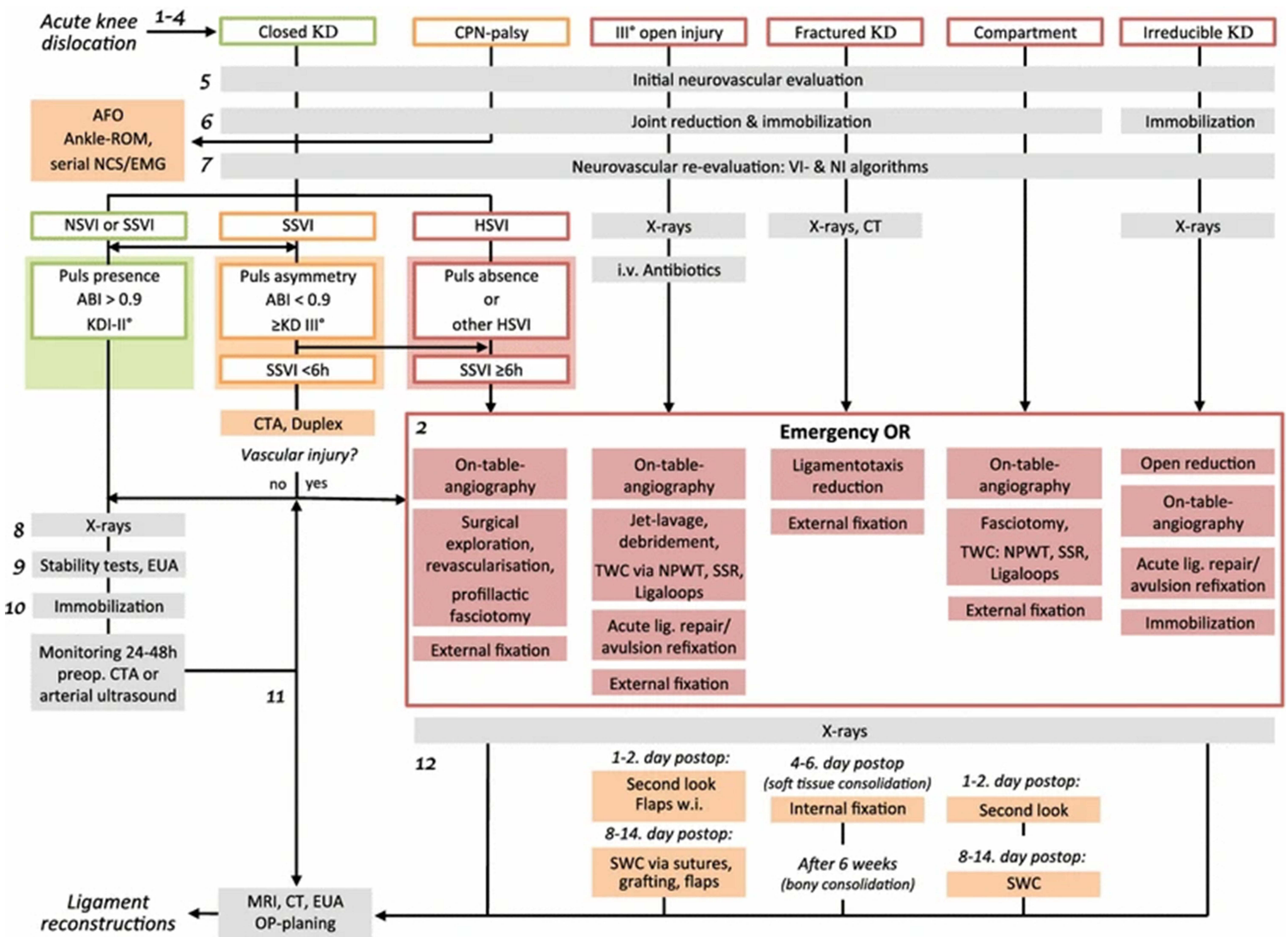

Figure 5 Acute knee dislocation treatment algorithm with temporizing knee-spanning external fixation. KD, knee dislocation; CPN, common peroneal nerve; AFO, ankle-foot orthosis; ROM, range of motion; NCS/EMG, nerve conduction study/electromyography; NSVI, no signs of vascular injury; SSVI, soft signs of vascular injury; HSVI, hard signs of vascular injury; EUA; examination under anesthesia: CTA: CT angiogram; TWC, traditional wound care; NPWT, negative pressure wound therapy; SSR, secondary surgical revision; SWC, secondary wound closure. Reproduced from Maslaris A, Brinkmann O, Bungartz M, Krettek C, Jagodzinski M, Liodakis E. Management of knee dislocation prior to ligament reconstruction: What is the current evidence? Update of a universal treatment algorithm. Eur J Orthop Surg Traumatol. 2018;28(6):1001–1015. doi:10.1007/s00590-018-2148-4,[16] with permission from Springer Nature.

definitive osseous or ligamentous reconstruction.[13,17,71] Additionally, several authors emphasize indications driven by the condition of the soft-tissue envelope. Open KDs, degloving injuries, or extensive abrasions benefit from temporary external stabilization that permits serial debridement and wound access while preventing further cartilage or neurovascular injury.[13,15–17] Additionally, in patients with morbid obesity, particularly following ultra-low-velocity KDs, commercial braces often fail to maintain concentric reduction, making KSEF the only reliable means to prevent early recurrence.[14,15,72] Patients with obesity with ultra-low velocity injuries also have higher rates of concomitant neurovascular injuries and postoperative complications following ligament reconstruction, which further justifies definitive management with KSEF in these patients.[73,74] Overall, precise clinical scenarios such as vascular compromise, open fractures, irreducible subluxations, fracture-dislocations, and morbid obesity should guide the selective application of KSEF to minimize morbidity, resource utilization, and potential complications. Further clarification and validation of standardized criteria is warranted to refine the utilization of this important orthopedic intervention.

A Note on Polytrauma

"Polytrauma" is also frequently cited as a clinical indication for KSEF in the setting of KD/MLKI.[12,15,16,75,76] This term is most recently defined in the 2014 Berlin consensus statement as an injury with an Abbreviated Injury Scale (AIS) score ≥ 3 in at least two distinct body regions, plus ≥ 1 of the following admission criteria: hypotension (systolic blood pressure

≤ 90 mmHg), unconsciousness (Glascow Coma Scale (GCS) score ≤ 8), acidosis (base deficit ≤ −6.0), coagulopathy (PTT ≥ 40 seconds or INR ≥ 1.4), and age (≥ 70 years).[77] Up to a third of patients with KD/MLKI present with head, chest, or abdominal injuries, and up to 60% sustain an associated fracture.[75,78,79] While the injury severity score (ISS) and new injury severity score (NISS) are available for quantitatively assessing polytrauma, specific KSEF application criteria in the setting of polytrauma are not available. If polytrauma is to be used as a primary indication for KSEF application following KD/MLKI, additional guidelines and protocols based on the NISS are needed.[80,81] This raises concern that KSEF may be applied more broadly than needed in the setting of polytrauma, specifically for knees that are sufficiently stable post-reduction in a brace or splint. A case series by Darabos et al highlights this controversy by demonstrating worse clinical outcomes in polytraumatized patients undergoing prolonged, staged management with KSEF compared to patients managed with shorter, more direct surgical interventions without KSEF.[82] In 14 polytraumatized patients with KDs, KSEF was applied selectively in three cases specifically in the setting of hemothorax, reflecting a more conservative approach aimed at reducing avoidable complications due to KSEF.[82] Thus, if there is no trauma-associated neurovascular injury and the reduction can be maintained non-invasively, a single-stage treatment protocol in the subacute phase without the use of KSEF may be sufficient in the polytraumatized patient with a KD. Ng et al provide a set of indications for KSEF in the setting of MLKI that does not include polytrauma and is instead based on vascular injury, open KD, fracture-dislocation, or an inability to non-invasively maintain reduction.[13] Thus, for KDs that are isolated or stable after reduction, alternative management strategies should be considered to avoid additional patient morbidity, overutilization of healthcare resources, and potential complications, even in the setting of polytrauma. Table 3 displays studies in the current literature that provide a set of indications for KSEF following KD/MLKI.

Outcomes

Few comparative studies have directly assessed outcomes of temporizing KSEF in the setting of KD/MLKI, which may be attributable to the wide range of possible injury patterns and subsequent difficulty controlling for confounding variables, as well as the rarity of this injury and treatment modality at baseline. While there are no studies directly comparing outcomes of KD/MLKI managed with temporizing KSEF to those managed without temporizing KSEF, there have been several retrospective studies within the past 15 years that have indirectly or secondarily assessed outcomes associated with temporizing KSEF (Table 4). The outcomes related to temporizing KSEF assessed in these studies include stiffness/arthrofibrosis/motion loss in seven studies, infection in three, compartment syndrome in two, heterotopic ossification in two, and ROM in two. Other variables that have been assessed include obesity, return to duty, MRI image quality, Oxford Knee Score, IKDC, Lysholm, SF-12 Mental and Physical components, and ligament stability.

Table 3 Studies Describing Indications for KSEF After KD/MLKI

Study	Open KD	Vascular Injury ± Surgery	Fracture-Dislocation	Insufficient Stability After Bracing ± Reduction	Compartment Syndrome	Morbid Obesity	Polytrauma
Maslaris[16]	✓	✓	✓	✓	✓	✗	✓
Lucidi[15]	✗	✓	✗	✓	✗	✓	✓
Ng[13]	✗	✓	✓	✓	✗	✗	✗
Lamont[71]	✓	✓	✓	✗	✗	✗	✗
Schenck[12]	✓	✗	✗	✓	✗	✓	✓
Levy[17]	✓	✓	✗	✓	✗	✗	✗
Fanelli[49]	✓	✓	✗	✓	✗	✗	✗
Mühlenfeld[83]	✓	✓	✓	✓	✗	✗	✗
Wascher[70]	✓	✓	✗	✗	✗	✗	✓
Bodendorfer[76]	✓	✓	✗	✓	✗	✗	✓

Note: ✓ = included as an indication; ✗ = not included as an indication.

Table 4 Studies Assessing Outcomes Related to KSEF Following KD/MLKI

Study Title (Author)	Publication Year	Study Design	Number of Patients (% with KSEF)	Outcome Measure(s) related to KSEF	Main Conclusion Related to KSEF
Mid-Term Results following Traumatic Knee Joint Dislocation (Watrinet et a)[7]	2023	Retrospective Cohort Study	38 (42%)	Arthrofibrosis, Compartment Syndrome	2x rate of arthrofibrosis and 5x rate of compartment syndrome with KSEF
Risk Factors for the Development of Heterotopic Ossification After Knee Dislocation (Whelan et al)[84]	2014	Retrospective Cohort Study	88 (18%)	HO	Significantly higher rate of KSEF application in HO group compared to no HO group (33.3% vs 10.3%, p=0.017) in univariable analysis
No effect of dislocation status at arrival in emergency department on outcomes in knee dislocation (Szymski et al)[85]	2024	Retrospective Cohort Study	120 (96%)	SSI, Arthrofibrosis, Limitation in ROM, Limitations in Everyday Life	Low rates of SSI (3.3%) and arthrofibrosis (5.0%). 23.6% with limitation in ROM. 50% minorly limited, 11.7% majorly limited in everyday life.
Obesity Is Associated with Significant Morbidity after Multiligament Knee Surgery (Lian et al)[86]	2020	Retrospective Cohort Study	108 (24%)	Obesity	No difference in KSEF application between BMI<35 and BMI≥35
Importance of Early Diagnosis and Care in Knee Dislocations Associated with Vascular Injuries (Teissier et al[87]	2019	Retrospective Case Series	16 (81%)	Oxford Knee Score	Mean Oxford Knee Score: Pre-trauma: 45.7±3.2 Post-trauma: 27.4±11.9
Clinical and Functional Results of 119 Patients with Knee Dislocations (Scarcella et al)[88]	2017	Retrospective Case Series	119 (88%)	Complications	Any complication (32%) Deep infection (13%) Pin site infection (2.9%) DVT (13%) PE (1.8%) HO (13%) Arthrofibrosis (14%)
Effect of Vascular Injury on Functional Outcome in Knees with Multi-Ligament Injury: A Matched-Cohort Analysis (Sanders et al)[35]	2017	Retrospective Matched-Cohort Study	48 (25%)	IKDC, Lysholm Knee Score, Final Knee ROM	Treatment with KSEF was not predictive of worse postoperative knee function
Staged protocol for initial management of the dislocated knee (Levy et al)[17]	2010	Retrospective Case Series	9 (100%)	ROM, IKDC, Lysholm, Stiffness, Deep Infection, HO	Mean ROM 97° (80–130°) Median IKDC 80 (30–95) Mean Lysholm 76.7 (46–95) 1/9 (11%) manipulation for stiffness 0 deep infections 4/9 (44%) HO
Surgical outcomes after traumatic open knee dislocation (King et al)[89]	2009	Retrospective Case Series	7 (100%)	SF-12 Physical and Mental, Infection, Amputation	Mean SF-12 Physical 40, Mental 50 Infection 43%, 1 amputation
How Do Spanning External Fixators on Knee Dislocation Patients Affect the Use of MRI and Knee Stability? (Javidan et al)[90]	2015	Retrospective Case Series	19 (100%)	MRI Image Quality, Ligament Stability at KSEF Removal	Scans needing repeat (16%) Knee Stability at KSEF Removal: 11/14 MCL, 4/16 LCL, 1/19 ACL, 3/19 PCL
External fixation increases complications following surgical treatment of multiple ligament knee injuries (Hughes et al)[21]	2021	Retrospective Cohort Study	136 (12.5%)	Complications	KSEF associated with significantly higher rate of complications (82% vs 29%, p=0.004)

(*Continued*)

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Table 4 (Continued).

Study Title (Author)	Publication Year	Study Design	Number of Patients (% with KSEF)	Outcome Measure(s) related to KSEF	Main Conclusion Related to KSEF
Factors Associated with Knee Stiffness following Surgical Management of Multiligament Knee Injuries (Hanley et al)[91]	2017	Retrospective Case Series	121 (8.3%)	Motion Loss	KSEF was not associated with motion loss
The Effect of Knee-Spanning External Fixation on Compartment Pressures in the Leg (Egol et al)[92]	2008	Prospective Cohort Study	25 (100%)	Change in Compartment Pressures, Incidence of Acute Compartment Syndrome	KSEF caused only transient pressure rises, 0% developed postoperative compartment syndrome
Knee dislocation and associated injuries: an analysis of the American College of Surgeons National Trauma Data Bank (Chowdhry et al)[93]	2020	Retrospective Cohort Study using ACS National Trauma Data Bank	6454 (6.3%)	Factors Associated with KSEF application	KSEF associated with MVC, open dislocation, popliteal artery injury.
Predictors of Knee Arthrofibrosis and Outcomes after Arthroscopic Lysis of Adhesions following Ligamentous Reconstruction (Bodendorfer et al)[76]	2019	Retrospective Case Control	121 (% treated with KSEF not reported)	Arthroscopic LOA	Univariable analysis of Arthroscopic LOA associated with KSEF: (OR: 12.81, CI: 3.03–54.20, P<0.001)
Risk of Post-operative Stiffness Following Multiligamentous Knee Injury Surgery Is Not Affected by Obesity (Bi et al)[94]	2022	Multicenter Retrospective Cohort Study	190 (14.7%)	Postoperative Stiffness Requiring MUA/LOA	Multivariable analysis of MUA/LOA for KSEF: (OR: 3.3, CI: 2.2–4.7, p<0.0001)
Return to duty following combat-related multi-ligamentous knee injury (Barrow et al)[95]	2017	Retrospective Cohort Study	46 (41%)	Return to Duty	Multivariable analysis of Return to Duty for KSEF (OR: 0.213, CI: 0.048–0.940, p=0.041)
External Fixator Application, 2-Stage Procedures, and Post-operative Infection Risk Are Higher in Multiligamentous Knee Injuries After Frank Knee Dislocations (Daniel et al)[10]	2024	Retrospective Cohort Study	88 (24%)	KSEF Application	Frank KDs associated with significantly higher rate of KSEF than non-dislocated MLKI (50% vs 5.8%, p<0.001)

Abbreviations: KSEF, knee-spanning external fixation; HO, heterotopic ossification; SSI, surgical site infection; ROM, range of motion; DVT, deep vein thrombosis; PE, pulmonary embolism; MUA/LOA manipulation under anesthesia/lysis of adhesions; MVC, motor vehicle collision; CI, confidence interval (95%); KD, knee dislocation.

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There are also a few studies that have investigated the use of hinged KSEF as an adjunct following ligament reconstruction.[55–57,96] The goal of hinged KSEF in this scenario would be to minimize the risk of motion loss and potential arthrofibrosis that may result from rigid casts, braces, and immobilization, as this can be associated with significant pain and poor functional outcomes.[7,97] Angelini et al demonstrated in a randomized controlled trial (RCT) that the use of hinged KSEF for subacute and chronic KD provides the same ligament stability and improved ROM and patient-reported outcomes (PROs) compared to rigid knee bracing in extension.[57] Stannard et al demonstrated in two prospective studies that hinged KSEF following KD is associated with significantly lower rates of ligament failure following repair/reconstruction.[55,56] Lastly, Sobrado et al found a high prevalence of osteoarthritis (64.5%) in patients with chronic KD, with no significant difference between the hinged KSEF and rigid knee brace groups.[96] These studies suggest that, overall, hinged KSEF following KD/MLKI to supplement ligament repair/reconstruction can be utilized safely and effectively, particularly when multiple ligaments are repaired at once.[57]

Complications

Infection

One of the most cited complications of KSEF is device-related infection, which occurs most frequently at the interface of the pin, bar and clamps.[18,98–104] Studies investigating the risk of infection associated with KSEF are largely in the setting of tibial plateau fractures rather than KD/MLKI.[105] Infection rates following KSEF for tibial plateau fractures range from 6.0% to 26.9% depending upon sterilization methods.[100,101,106] Various contributing factors have been described, including clamp/bar adjustment post sterilization, increased time in the operating room, and overlapping pin sites.[101,104,107–109] However, it has also been suggested that KSEF is not associated with infection.[110] While there is a lack of consensus regarding the standard protocol for pin site care, it has been encouraged to adopt a consistent approach until further high-quality evidence is established.[102,104,111–114] Specific strategies for minimizing the risk of infection due to KSEF include changing gloves after device manipulation, protecting soft tissues with drill sleeves, using sharp drill bits, and avoiding thermal and ischemic necrosis of the bone and skin.[104]

Arthrofibrosis

A recent systematic review by de Fortuny et al found that arthrofibrosis is the most common complication following surgically treated MLKI, with an incidence of 8.4%.[115] This complication can have devastating consequences for the patient.[7,97,116] Notably, KSEF application has been found to be associated with an increased risk of arthrofibrosis.[7,76,94] Thus, prolonged KSEF use may contribute to arthrofibrosis, although it remains unclear whether this is due to the device itself or to injury severity.[10] Arthrofibrosis following KD/MLKI may be prevented with the use of immediate knee motion, shorter surgery time, minimizing soft tissue damage, and utilization of HEF.[58,116,117] If arthrofibrosis does result, arthroscopic arthrolysis of adhesions can be performed, as this has been demonstrated to be a safe and effective way to restore ROM following acute KD.[118,119]

Heterotopic Ossification

Heterotopic ossification (HO) is one of the most common complications after KD/MLKI, affecting 21–43% of patients.[11,120–122] Heterotopic ossification in the knee can lead to significant pain, stiffness, arthrofibrosis, and mechanical block, often requiring surgical excision.[11,84,120–127] While trauma-induced HO has been studied, very little is known regarding the risk factors and pathophysiology of HO following KD/MLKI, including its anatomical distribution and functional impact.[128–135] Available evidence suggests HO commonly forms in the medial and posterior compartments of the knee, particularly following posterior cruciate ligament (PCL) reconstruction or extensive soft tissue trauma.[84,121,122,136–140] Additionally, surgical factors such as tunnel drilling, reamed tibial nailing, or KSEF application use may contribute to HO by leaving behind bone debris or hematoma that stimulate bone formation.[84,139,141–143] The association between HO and KSEF may result from both mechanical limitations in joint motion and the underlying severity of the injury and/or surgery.[21] It is unknown whether trauma from the initial injury, subsequent surgery and management, or a synergistic effect yields a greater risk of HO following KD/MLKI. KSEF is often applied in the setting of polytrauma, which makes it challenging to isolate its specific contribution to HO from other potentially contributory factors.[15,16] For example, injury severity score (ISS) ≥ 26 has been shown to significantly increase the risk of severe HO, possibly due to a more intense systemic inflammatory response.[120] Additionally, motion loss, which is frequently observed in patients with prolonged KSEF use, is strongly associated with HO.[21] Therefore, the observed association between KSEF and HO may not be directly related to KSEF itself.

Compartment Syndrome

Few studies have investigated the risk of compartment syndrome associated with KSEF application, primarily in the setting of tibial plateau fractures. Watrinet et al found that compartment syndrome occurred in 25% of patients with KDs treated with KSEF compared to 5% in those treated without KSEF.[7] Stark et al found an incidence of 53% in 17 tibial plateau fracture-dislocations treated with temporizing KSEF, suggesting that KSEF placement itself may precipitate compartment syndrome following severe knee injuries.[144] The authors recommended careful monitoring of tibial plateau fracture-dislocations for compartment syndrome after KSEF placement. However, a prospective series that included KDs found only transient pressure spikes and no postoperative compartment syndrome after immediate KSEF, suggesting the KSEF itself is not a primary driver when applied correctly.[92]

Deep Vein Thrombosis

Patients undergoing KSEF in the setting of KD/MLKI may also face increased risk of deep vein thrombosis (DVT) and pulmonary embolism (PE).[145–148] This risk may be further exacerbated by prolonged immobility following these injuries.[149] A prospective study by Sems et al evaluated 148 external fixation devices applied for lower extremity trauma, including 10 KDs, instituting low-molecular-weight heparin (LMWH) prophylaxis and early mobilization.[147] Duplex ultrasonography performed 1–3 days prior to frame removal revealed a 2.1% incidence of DVT, with no hemorrhagic complications, which aligns with DVT rates seen in historical controls. Similar findings were reported in a study of elective KSEF use, with an overall thromboembolic event incidence of less than 1% when patients at high risk were treated with thromboprophylaxis.[148] These findings suggest that early restoration of limb length, alignment, and stability to enable early joint mobilization may contribute to the prevention of thromboembolic events when combined with the appropriate prophylactic measures.

Other Considerations

Psychological Impact

It is important to also consider the potential for KSEF to create psychological distress and aesthetic concerns for patients, which may affect adherence to treatment and overall quality of life during the recovery period following KD.[150] It has been demonstrated that patients with strong social support can better manage the stressors of external fixation.[151] It has also been demonstrated that patients who experience psychological distress may have less adherence to their rehabilitation protocols, impacting recovery.[152] When there are no definitive indications for KSEF, the added patient morbidity and hospitalization costs and time as well as the psychological impact of KSEF should be a primary consideration in management. The necessity for stability must be carefully weighed against the risks of morbidity, complications, and their effects on patient comfort and adherence.

MRI Safety

Studies focusing on the MRI safety of KSEF indicate that MRI can be performed safely with these devices in place under the proper conditions.[153,154] This is important because all patients with suspected MLKI should undergo MRI, and the urgent placement of a KSEF device can prevent this if MRI safety is not clearly understood.[1] A recent systematic review of 358 MRIs found zero cases of serious patient harm, with no burns or instability, and a 1.1% rate of minor patient discomfort that resolved without injury.[155] Additionally, while the presence of a KSEF device does introduce artifact and signal noise on MRI, literature suggests high-quality images are usually still achievable.[156,157] However, significant variability exists regarding institutional policies and clinician comfort levels with performing MRI in patients with external fixators.[153] A survey study by Marcel et al revealed a lack of consensus and widespread absence of formal institutional guidelines, contributing to delayed imaging and potentially impacting clinical outcomes negatively.[153] Given these findings, clinicians are encouraged to perform thorough risk assessments, reference manufacturer guidelines as a baseline, and closely coordinate with their medical and radiological teams. The broader consensus in current literature indicates that while definitive universal guidelines remain elusive due to configuration variability, MRI can and should be utilized safely and effectively in the management of patients with a KSEF for KD/MLKI, provided proper precautions and multidisciplinary collaboration are observed.[153,155,156]

Cost

A US national database study found that the average total charges associated with KD were $63,138, which increase significantly in patients with obesity and morbid obesity to $72,608.[158] Furthermore, staged surgical treatment, which often includes temporizing KSEF, is significantly more expensive than a single-stage repair.[159] Notably, one Level I trauma center analysis found that hardware alone for an external fixator frame costs approximately $5,900 per case in the US, compared to $50 in low-income countries.[160,161] Furthermore, in developing countries, external fixators are reused up to 10 times.[161] While there are important ethical considerations regarding the reuse of external fixators, Dirschl et al demonstrated that reducing costs via device reuse can be implemented safely and effectively.[162] Overall, KSEF is a costly intervention in the US with significant cost variability, which presents a unique opportunity for cost savings in trauma care.[163]

Conclusion

Knee-spanning external fixation is a commonly used tool in the acute and postoperative management of knee dislocations and multiligament knee injuries. Current evidence broadly supports its use in scenarios involving vascular compromise, knee fracture-dislocations, severe soft-tissue trauma, difficulty with maintaining reduction via non-invasive means, morbid obesity, postoperative graft protection, and potentially polytrauma. Despite its widespread application, controversy persists regarding its precise indications, optimal timing, and associated complications, necessitating judicious utilization and individualized decision-making. Further high-quality studies and updated guidelines are needed to clarify these considerations, refine treatment algorithms, and improve outcomes.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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