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Nursing Interventions for Preventing Complications Associated with External Fixation Devices in Orthopedic Patients

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ABSTRACT: External fixation is a crucial orthopaedic technique for complex fractures and limb deformity but poses risks like infection and nonunion. Evidence stresses the importance of standardized nursing practices for external fixator care to enhance patient outcomes. Effective guidelines recommend aseptic care, regular inspections, and patient education. Pin-site infection rates can be influenced by cleaning techniques, with chlorhexidine showing promise over povidone-iodine. Antimicrobial dressings also reduce infection risks. The Checketts–Otterburn classification aids in identifying infections, and consistent care is vital. Systematic assessments and educational resources are essential for managing complications and improving patient satisfaction. Despite advancements in

material science for pin coatings, diligent nursing care remains critical. Persistent variability in practice highlights the necessity for standard protocols and ongoing education.

INTRODUCTION

External fixation is an orthopaedic method in which pins or wires are inserted into bone and connected to an external frame to stabilise fractures, correct deformity, transport bone, or protect soft tissues, and it is particularly valuable in open fractures, comminuted fractures, pelvic injuries, infected nonunion, and damage-control situations [1]. The device allows access to soft tissues, permits early mobilisation in selected patients, and can be adjusted over time, but its percutaneous pins breach the skin barrier and create a direct route for microbial colonisation and deep infection [2]. Pin-site infection is the most frequently reported complication of external fixation, and reported incidence varies widely because of differences in definitions, follow-up, anatomical site, and care protocols [3]. Superficial infection may begin with erythema, swelling, tenderness, and discharge, and if it is not recognised early it can progress to deep infection, osteomyelitis, septic arthritis, and systemic sepsis [4]. Other important complications include neurovascular injury, compartment syndrome, pain, pin loosening, pin breakage, frame failure, nonunion, malalignment, joint stiffness, deep vein thrombosis, and pulmonary embolism [5]. Nurses are central to prevention because they perform serial assessment, aseptic pin-site care, dressing changes, neurovascular observations, pain assessment, thromboprophylaxis, and patient education throughout the hospital stay and at discharge [6]. Evidence indicates that nursing knowledge and practice regarding external fixation care are often suboptimal and that practice varies across units and countries [7]. The absence of structured nursing protocols is associated with higher rates of preventable infection and other adverse outcomes, whereas guideline-based care improves nurses' knowledge and practice [8]. Patient education is also essential because patients and caregivers must continue pin-site care, recognise warning signs, and adhere to activity restrictions after discharge [9]. Contemporary reviews therefore recommend a multicomponent, nurse-led prevention bundle rather than isolated interventions such as a single dressing change or a single teaching session [10]. Such a bundle should integrate pin-site infection prevention, neurovascular assessment, pain management, thromboprophylaxis, mechanical stability surveillance, psychosocial support, and discharge follow-up [11]. The present article provides a comprehensive evidence-based review of nursing interventions for preventing complications associated with external fixation devices in orthopaedic patients, and it synthesises contemporary guidance, systematic reviews, randomised trials, and nursing studies to inform practice, education, and quality improvement [12, 13].

Pathophysiology and Risk Factors of External Fixation Complications

Pin-site infection begins when bacteria colonise the pin–skin interface, where the pin disrupts the skin barrier and creates a moist, warm, and protein-rich microenvironment that supports microbial adherence and biofilm formation [14]. Coagulase-negative staphylococci, Staphylococcus aureus, Pseudomonas aeruginosa, and enteric organisms are commonly isolated, and biofilm formation protects microorganisms from host defences and systemic antibiotics [15]. This explains why established infection often persists until the pin is removed or exchanged and why prevention is more effective than late treatment [16]. Risk factors for pin-tract infection include diabetes mellitus, smoking, obesity, male sex, non-urban residence, agricultural occupation, lower educational level, prolonged initial disease duration, and prolonged time to bone union [17]. Local factors such as pin-site inflammation, excessive pin-site motion, skin maceration, poor hygiene, inadequate pin care, and prolonged external fixation further increase risk [18]. Systemic factors such as immunosuppression, malnutrition, and peripheral vascular disease impair tissue repair and host defence and should be addressed during nursing assessment [19]. Neurovascular complications may occur at pin insertion or later because of swelling, haematoma, constrictive dressings, or compartment syndrome, and serial neurovascular assessment is therefore mandatory [20]. Mechanical complications such as pin loosening, pin breakage, and frame failure can result from inadequate pin purchase, excessive loading, bone resorption around the pin, or failure to dynamise the frame appropriately [21]. Pin loosening is especially important because a loose pin creates a micro-mobile interface that causes soft-tissue irritation, increases discharge, and predisposes to infection [22]. Deep vein thrombosis and pulmonary embolism are recognised risks after major orthopaedic trauma and prolonged immobility, and systematic nursing risk assessment and prophylaxis are required [1]. The multifactorial nature of these complications means that effective prevention requires a coordinated bundle targeting infection, neurovascular compromise, pain, mechanical stability, thrombosis, and self-management simultaneously [2].

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Pin Site Infection: Assessment, Classification, and Prevention

Accurate and consistent pin-site assessment is the foundation of infection prevention, and the Checketts–Otterburn classification remains a widely used system for grading infection and guiding clinical decisions [10]. The classification distinguishes minor infections from major infections and links each grade to specific clinical features and escalation requirements [11]. Nurses should assess each pin site at least once per shift for erythema, swelling, tenderness, discharge, odour, and skin integrity, and they should compare findings with previous assessments and with the contralateral limb [12]. Aseptic technique is mandatory during every dressing change, and the nurse should use sterile gloves, single-use non-shedding gauze or swabs, and a fresh cleansing solution for each pin site to avoid cross-contamination [13]. The choice of cleansing solution remains debated, but chlorhexidine gluconate in alcohol has been shown in randomised trials to produce significantly lower pin-site infection rates than povidone-iodine, while normal saline remains an acceptable alternative when antiseptics are contraindicated or poorly tolerated [14]. A randomised controlled trial comparing polyhexamethylene biguanide-impregnated gauze with plain saline gauze found that antimicrobial gauze reduced the risk of pin-tract infection from 4.5% to 1.0%, supporting the use of antimicrobial dressings in high-risk patients [15]. National guidance recommends that pin sites should be kept covered, that dressings should be changed according to unit protocol and whenever they become soiled or wet, and that scabs should not be forcibly removed unless there is evidence of infection or excessive crusting [5]. The frequency of pin-site cleaning varies across protocols, with some centres recommending daily cleaning and others recommending weekly cleaning for calm pin sites, and the evidence suggests that either approach is acceptable provided that technique is aseptic and sites are inspected regularly [6]. Table 1 summarises the Checketts–Otterburn classification and corresponding nursing actions, and it provides a practical framework for consistent documentation and escalation [10]. Table 2 summarises the principal nursing interventions for preventing external fixation complications and the supporting evidence, and it demonstrates that a multicomponent approach is more effective than any single intervention [2].

Table 1. Checketts–Otterburn classification of pin-site infection and corresponding nursing actions

Grade	Clinical features	Nursing action
1	Slight redness and little discharge	Continue aseptic pin-site care, increase inspection frequency, and reinforce hygiene education [10][11]
2	Redness, discharge, and pain	Obtain wound swab, notify orthopaedic team, consider antimicrobial dressing, and document findings [10][15]
3	Grade 2 changes without improvement on oral antibiotics	Escalate to senior clinician, prepare for possible pin removal or exchange, and continue wound care [10][12]
4	Severe soft-tissue infection involving several pins	Urgent medical review, intravenous antibiotics, possible surgical debridement, and intensive nursing monitoring [10][13]
5	Radiographic changes of osteomyelitis	Coordinate diagnostic imaging and specialist orthopaedic management and continue wound and systemic care [10][14]
6	Infection after fixator removal	Monitor pin sites after removal, obtain cultures, and provide wound care and follow-up [21][22]

Table 2. Summary of nursing interventions for preventing external fixation complications

Complication	Nursing intervention	Supporting evidence
Pin-site infection	Aseptic cleansing with chlorhexidine or saline, antimicrobial dressings, regular inspection, prompt swabbing, and escalation	[5][6][8][9][10]
Neurovascular compromise	Serial neurovascular assessment including pulses, capillary refill, colour, temperature, sensation, and motor function	[1][11][20]

Pain	Systematic pain assessment, multimodal analgesia, positioning, distraction, and relaxation techniques	[14][16]
Deep vein thrombosis	Risk assessment, early mobilisation, ankle pumps, compression, and adherence to pharmacological prophylaxis	[1][18][22]
Pin loosening and frame failure	Inspect pin security, frame connections, and limb alignment at every shift and dressing change	[17][21][22]
Nonunion and malalignment	Monitor alignment, weight-bearing status, and dynamisation schedule and report abnormalities	[2][17][21]
Patient knowledge deficit	Structured education on pin care, warning signs, hygiene, activity, and follow-up	[3][4][15]

Neurovascular Assessment and Prevention of Compartment Syndrome

Neurovascular assessment is a critical nursing intervention for patients with external fixators because the device and the underlying injury can compromise peripheral circulation and nerve function, and early detection of deterioration is essential to prevent irreversible ischaemia and permanent neurological deficit [1]. The focused neurovascular assessment includes bilateral comparison of peripheral pulses, capillary refill time, skin colour, skin temperature, sensation, and motor function, and pain and oedema should also be evaluated because disproportionately severe pain is an early warning sign of compartment syndrome [2]. Nurses should perform neurovascular observations at least every hour for the first 24 hours after application of an external fixator, then according to unit protocol and the patient's clinical condition, and any deviation from baseline should be reported immediately to the orthopaedic team [3]. Compartment syndrome is a surgical emergency that can occur in the presence of an external fixator, particularly after high-energy trauma, and the classical signs of pain out of proportion, pain on passive stretch, paraesthesia, pallor, pulselessness, and paralysis are not all present in every case [4]. The nurse should ensure that dressings and bandages are not constrictive, that the limb is positioned at the appropriate level to promote venous return without compromising arterial perfusion, and that the patient receives adequate analgesia because uncontrolled pain can mask or mimic neurovascular deterioration [5]. Patient education should include instructions to report new numbness, tingling, weakness, colour change, or severe pain immediately, and this education should be reinforced at every shift and before discharge [6]. Neurovascular assessment documentation should be contemporaneous, standardised, and easy to interpret because delayed recognition of compartment syndrome is a recognised cause of preventable harm and litigation [7].

Pain Management and Patient Comfort

Pain is a common and distressing symptom in patients with external fixators, and it arises from the injury itself, the surgical procedure, pin-site inflammation, muscle spasm, pin loosening, distraction, and psychological distress [8]. Uncontrolled pain reduces mobility, increases the risk of deep vein thrombosis and pneumonia, impairs sleep and nutrition, and contributes to anxiety and depression, all of which can delay rehabilitation and increase length of hospital stay [9]. Nurses should assess pain systematically using a validated scale such as the numerical rating scale or the visual analogue scale, document the location, quality, intensity, and aggravating and relieving factors, and administer multimodal analgesia according to prescription and unit protocol [10]. Non-pharmacological nursing interventions for pain include positioning and support of the limb, application of cold therapy when appropriate, distraction, relaxation techniques, guided imagery, and careful handling during dressing changes and repositioning [11]. The nurse should also evaluate the effectiveness of analgesia, monitor for adverse effects such as sedation, respiratory depression, constipation, and nausea, and communicate unresolved pain to the medical team so that the analgesic plan can be adjusted [12]. Patient education about pain expectations, the importance of reporting pain promptly, and the appropriate use of prescribed analgesics is an essential component of nursing care and should be provided in a culturally and linguistically appropriate format [13]. A structured nursing intervention protocol for patients with Ilizarov external fixation has been shown to improve pain scores, reduce anxiety, and improve joint function, which supports the integration of pain management into a broader multidisciplinary rehabilitation plan [16].

Prevention of Deep Vein Thrombosis and Venous Thromboembolism

Patients with external fixators are at increased risk of deep vein thrombosis and pulmonary embolism because of trauma, surgery, immobility, limb swelling, and endothelial injury, and venous thromboembolism prophylaxis is therefore an essential

component of orthopaedic nursing care [17]. The nurse should perform a validated risk assessment on admission and reassess the patient regularly, and the assessment should take into account age, body mass index, previous thromboembolism, malignancy, thrombophilia, immobility, and the nature and duration of surgery [18]. Mechanical prophylaxis, including graduated compression stockings, intermittent pneumatic compression, and early mobilisation with ankle pumps and foot exercises, should be used when pharmacological prophylaxis is contraindicated or as an adjunct to it [19]. Pharmacological prophylaxis with low-molecular-weight heparin or other agents should be administered at the prescribed dose and time, and the nurse should monitor for bleeding, thrombocytopenia, and other adverse effects [20]. Patient education should include information about the signs and symptoms of deep vein thrombosis and pulmonary embolism, the importance of adherence to prophylaxis, and the need to report calf pain, swelling, chest pain, breathlessness, or haemoptysis immediately [21]. The nurse should also encourage early mobilisation, adequate hydration, and avoidance of prolonged dependency of the limb because these measures reduce venous stasis and complement pharmacological prophylaxis [22]. A nursing protocol based on structured risk assessment has been reported to reduce the incidence of venous thromboembolism in patients with Ilizarov external fixation, which demonstrates that targeted nursing risk assessment and prophylaxis can improve outcomes in this population [1].

Prevention of Pin Loosening, Nonunion, and Malalignment

Mechanical complications of external fixation, including pin loosening, pin breakage, frame failure, nonunion, and malalignment, are important causes of treatment failure and reoperation, and nurses play a key role in their early detection and prevention [2]. Pin loosening can be detected by gentle manual assessment of pin security during dressing changes, by observing for increased pin-site discharge or pain, and by monitoring for changes in frame stability, and any suspicion of loosening should be reported promptly because a loose pin is a precursor to infection and loss of fixation [3]. The nurse should inspect frame connections, clamps, rods, and wires at every shift, ensure that all components are tightened according to the manufacturer's instructions, and document any abnormalities [4]. Weight-bearing status and dynamisation schedules should be implemented as prescribed, and the nurse should reinforce patient education about activity restrictions, the use of walking aids, and the importance of not adjusting the frame independently [5]. Nonunion and malalignment may be suspected when there is persistent pain, instability, deformity, or failure to progress on serial radiographs, and the nurse should communicate these concerns to the orthopaedic team and reinforce the need for regular follow-up [6]. A multicentre prospective study comparing hydroxyapatite-coated pins with stainless steel pins found no significant difference in pin-track infection rates, which suggests that pin design alone does not eliminate the risk of mechanical and infectious complications and that nursing surveillance remains essential [20]. The nurse should also monitor nutritional status because adequate protein, calcium, vitamin D, and vitamin C intake supports bone healing and reduces the risk of nonunion and infection [7].

Patient Education and Self-Management

Structured patient education is one of the most effective nursing interventions for preventing external fixation complications because patients and their families are responsible for daily pin-site care, hygiene, activity modification, and recognition of warning signs after discharge [8]. Education should begin before surgery and continue throughout the hospital stay, and it should be delivered in a structured, repetitive, and multimodal format that includes verbal instruction, written materials, demonstrations, and return demonstrations [9]. The content should cover the purpose and function of the external fixator, the principles of pin-site care, hand hygiene, cleansing technique, dressing-change frequency, and the importance of keeping pin sites clean and dry [10]. Patients should be taught to recognise and report signs of infection such as redness, swelling, pain, discharge, odour, and fever, as well as signs of neurovascular compromise such as numbness, tingling, weakness, and colour change [11]. Education should also address pain management, activity restrictions, weight-bearing status, exercises to maintain joint range of motion and muscle strength, the importance of follow-up appointments, and the process of device removal [12]. A self-management protocol for patients with lower limb external fixators has been shown to reduce the incidence of pin-site infection, increase knowledge and self-reported practices, and improve patient satisfaction, which supports the routine integration of structured self-management education into nursing care [15]. Similarly, nursing guidelines focused on self-care strategies have been associated with significant improvements in knowledge, practice, activities of daily living, and pain scores and have been recommended for widespread implementation in orthopaedic departments [14]. The nurse should assess the patient's health literacy, learning preferences, and psychosocial readiness and should adapt the education plan accordingly to ensure that it is accessible, acceptable, and effective [13].

Psychosocial Support and Quality of Life

External fixation has a profound psychosocial impact on patients because the device is visible, restricts mobility and sleep, interferes with dressing and personal hygiene, and often requires prolonged treatment that disrupts work, family life, and social roles [16]. Patients commonly experience anxiety, depression, frustration, body image disturbance, social isolation, and fear of complications or device failure, and these psychological factors can impair adherence to treatment and rehabilitation [17]. Nurses should screen for psychological distress, provide emotional support, encourage expression of concerns, and refer patients to psychological services when indicated [18]. Peer support, patient narratives, and structured educational interventions can reduce anxiety and improve coping, and the nurse should facilitate access to these resources when available [19]. The nurse should also involve family members and caregivers in education and care planning because social support is a strong predictor of adherence and positive outcomes [20]. Quality of life should be assessed using a validated instrument, and the findings should inform individualised care planning and follow-up [21]. A nurse-led digital care programme for patients with external fixation has been associated with modest improvements in pain and function at 4 and 12 weeks, although the effect was not sustained at 24 weeks, which suggests that digital interventions may be a useful adjunct but not a substitute for comprehensive face-to-face nursing care [22].

Interprofessional Collaboration and Nursing Competence

Effective prevention of external fixation complications requires close collaboration among orthopaedic surgeons, nurses, physiotherapists, occupational therapists, dietitians, pharmacists, and microbiologists, and the nurse acts as the coordinator of this interprofessional team at the bedside [1]. Nurses should participate in daily multidisciplinary rounds, communicate assessment findings clearly and concisely, and advocate for timely medical review when complications are suspected [2]. Nursing competence in external fixation care should be developed through structured education, simulation, competency assessment, and regular in-service training because evidence shows that nurses' knowledge and practice improve significantly after targeted educational interventions [3]. A quasi-experimental study of nursing care guidelines for external fixation demonstrated a statistically significant improvement in nurses' knowledge and practice after the intervention and recommended ongoing training courses for all orthopaedic nurses [4]. Another study found that only a small proportion of nurses had satisfactory knowledge of pin-site infection and that practice was inconsistent, which highlights the need for continuing professional development and clinical audit [5]. The nurse should also engage in reflective practice and adverse event reporting because near-miss and incident data can identify system failures and inform quality improvement initiatives [6]. Standardised nursing documentation, checklists, and care bundles can reduce variation in practice and improve adherence to evidence-based guidelines, and these tools should be co-designed with frontline nurses to ensure that they are practical and acceptable [7].

Discharge Planning and Follow-Up

Discharge planning for patients with external fixators must be individualised, comprehensive, and initiated early in the hospital stay because the transition from hospital to home is a high-risk period for preventable complications [8]. The nurse should assess the patient's home environment, availability of a caregiver, access to transportation, financial resources, and ability to perform pin-site care independently or with assistance [9]. Written discharge instructions should include contact details for the orthopaedic unit, the date and time of follow-up appointments, a list of warning signs that require urgent medical attention, and clear guidance on medications, activity, hygiene, and dressing changes [10]. The nurse should provide a supply of dressings and cleansing solutions, demonstrate their use, and ensure that the patient or caregiver can perform the procedure correctly before discharge [11]. Follow-up should include telephone or telehealth contact within the first week after discharge, and the nurse should use this opportunity to reinforce education, address concerns, and identify early signs of complication [12]. Patients should be advised to keep pin sites covered and dry, to shower rather than bathe, to avoid applying creams or ointments unless prescribed, and to avoid touching the pins unnecessarily [13]. The nurse should also coordinate with community nursing services when ongoing wound care is required and should ensure that the patient has a clear pathway for urgent review if complications arise [14]. A structured discharge checklist and a nurse-led follow-up clinic can improve continuity of care and reduce readmission rates, and these should be considered as standard components of external fixation services [15].

CONCLUSION

External fixation, while valuable, poses risks such as pin-site infection and neurovascular compromise that can be minimized through consistent, evidence-based nursing care. Effective prevention strategies include systematic assessments, aseptic techniques, and interprofessional collaboration. A multicomponent, nurse-led protocol has proven more effective than

fragmented approaches, highlighting the need for structured education and support post-discharge. However, many nurses lack the necessary knowledge and resources, necessitating commitment to competency-based education and standard care practices. Ultimately, nursing interventions are crucial for reducing complications and enhancing patient safety and recovery outcomes.

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