TEMPLATE

RQ [##]: [**Are there well-defined criteria for performing definitive internal fixation immediately after index debridement?]**

Section 1: Background (<300 words):

Traditionally, open fractures have been managed with thorough debridement followed by temporary stabilization using an external fixator. Definitive internal fixation and soft-tissue reconstruction were typically delayed until the surgeon was confident that the wound was free of infection. In recent years, however, this paradigm has evolved. Increasingly, trauma centers advocate immediate definitive fixation with intramedullary nailing or plating for selected open fractures characterized by limited contamination and minimal comminution, provided that definitive soft-tissue coverage can be achieved within 24–36 hours.

Nevertheless, the definitions of “limited contamination” and “minimal comminution” remain poorly standardized. No universally accepted criteria exist to objectively identify patients who are suitable for such an aggressive treatment strategy, leaving considerable room for subjective interpretation and inter-surgeon variability.

Several other aspects of open-fracture management also remain controversial. These include the optimal timing of debridement, particularly the validity of traditional emergency debridement thresholds, as well as the selection of the most appropriate reconstructive technique for specific soft-tissue defects, including the choice between local or regional flaps and microsurgical free-tissue transfer.

Section 2: Data extraction table

For each included study: Author/Year, Study Design, Sample Size, Population, Intervention/Comparator, Key Outcomes, Results, and Follow-up duration.

Example table template (can be edited as per the question)

S.no	Author, year of publication, Country	Study Design	Sample Size (add individually for each group if multiple	Study population (Inclusion and exclusion criteria)	Groups compared	Results

			groups compared)			
1	Luo et al. [1], 2023, China	retrospective study without a control group	20 patients with Gustilo IIIB open forearm fractures	Inclusion Criteria: Patients diagnosed with Gustilo type IIIB open forearm fractures, Exclusion Criteria: Patients with acute heart or cerebrovascular disease; those unable to tolerate surgery; treatment interruption; or those lost to follow-up	No groups compared	Successful limb salvage was achieved in 100% of the 20 cases involving Gustilo IIIB open forearm fractures, No deep infections or osteomyelitis occurred, 13 of 20 patients (65%) achieved "excellent" or "good" forearm function, Three patients (15%) developed bone nonunion but achieved healing after subsequent bone grafting
2	Gopal et al. [2], 2004, England	retrospective case series	33 patients with 34 open tibial fractures (IIIb or IIIc)	Inclusion Criteria: Patients with Gustilo grade IIIb or grade IIIc open tibial fractures treated with a specific "fix and flap" protocol, Exclusion Criteria: severe concomitant head injuries or lost to	Early flap cover vs. Delayed flap cover	Deep infection occurred in only 6.1% of patients. The mean SF-36 scores were 49 for physical health and 62 for mental health, which are lower than the general population. All patients expressed satisfaction at having retained their own legs, even though many suffered from ankle stiffness (56%) or a persistent limp (61%

				follow-up		
3	Jitprapaikulsarn et al. [3], 2021, Thailand	retrospective case series	7 patients with Gustilo type IIIB open fractures of the distal tibia (concurrent internal fixation and distally based sural flap coverage)	Inclusion criteria: Gustilo type IIIB open fractures of the distal diaphysis or distal metaphysis of the tibia, Exclusion Criteria: Intra-articular fractures of the distal tibia; concomitant vascular injuries; and severe crush injuries or extensive open wounds on the posterior half of the affected leg	No groups compared	All 17 fractures (100%) united within a mean duration of 22.6 weeks, Every distally based sural flap (DBSF) survived;
4	Naique et al. [4], 2006, England	comparative retrospective study	73 consecutive grade IIIB open tibial shaft fractures	Inclusion Criteria: grade IIIB open tibial shaft fractures managed in a combined orthopaedic and plastic surgical, Exclusion Criteria: Open fractures of the tibial plateau and ankle. Patients	Primary vs tertiary group (Patients who were initially managed at local hospitals and then transferred to the specialist center)	All flap failures (9.5%) and nearly all deep infections occurred in the "tertiary group" (patients transferred from other hospitals). Revision of the initial skeletal fixation was required in 47% of transferred patients due to incorrect implant selection or instability. The study found no relationship between infection rates and whether debridement occurred before or after the traditional "six-hour rule". 67% of patients had returned to employment at the time of review

				requiring primary amputation		
5	Minehara et al. [5], 2023, Japan, Argentina, Italy, England, Canada, and USA	literature review	-	-	debrided before vs. after 6 hours and before vs. after 12 hours	The adequacy and thoroughness of the initial debridement are more critical than the specific time from injury to surgery. Early administration of systemic antibiotics (ideally within one hour) remains one of the most vital factors in preventing infection
6	Varma et al. [6], 1974, India	comparative retrospective study	91 open fractures. Patients managed conservatively (53 cases) vs those managed by primary internal fixation (38 cases)	Inclusion Criteria: Patients with open fractures, No exclusion criteria	Primary Internal Fixation Group vs conservative treatment	Patients treated with primary internal fixation had significantly fewer "poor" results (5.2%) compared to those treated conservatively (22.6%). Internal fixation resulted in perfect anatomical alignment and union in 94.8% of cases, whereas conservative treatment led to more deformities and shortening

Section 3: Results summary write-up (upto 500 words)

Well-defined criteria for performing definitive internal fixation in open fractures primarily depend on the fracture configuration, the degree of wound contamination, and the ability to achieve stable soft-tissue coverage [4]. For diaphyseal fractures, intramedullary nailing is specifically recommended when there is minimal contamination and mild comminution, provided that definitive soft-tissue cover can be completed within 24 to 36 hours of the skeletal fixation. Conversely, external fixation remains the standard for cases involving severe wound contamination, extensive soft-tissue defects, bone loss exceeding 2 cm, or when there is a significant delay in achieving wound coverage

In the case of forearm fractures, internal fixation with plates and screws is often the "first choice" because anatomical reduction is required to restore rotational function, though it is still contingent on having sufficient soft tissue to cover the implant site [1].
Regarding the duration from the time of injury, current evidence emphasizes a 72-hour window for definitive "fix and flap" procedures, where both skeletal stabilization and wound coverage are achieved in a single or very closely timed surgical episode [2]. While the historic "six-hour rule" suggests that debridement must occur immediately to prevent exponential bacterial growth, multiple studies indicate that the adequacy and thoroughness of the initial debridement are far more critical to the outcome than the speed at which it is performed. However, delay in debridement is not recommended for wounds with gross contamination (such as agricultural, marine, or sewage debris), severe polytrauma, acute compartment syndrome, or vascular injury, all of which necessitate immediate emergency surgery.
The presence of comorbidities and the patient's overall physiological stability also dictate the timing and type of fixation. Initial surgical intervention, including debridement and provisional stabilization, is typically only carried out when hemodynamic conditions allow. For patients with life-threatening injuries or severe multi-system trauma, temporary external fixation is often used first as part of a damage-control strategy, with a planned conversion to definitive internal fixation once the patient is stabilized and the wound condition has improved, ideally within 10 to 14 days. Additionally, factors such as smoking history or acute cerebrovascular disease can complicate the recovery of free flaps and bone union, influencing whether a surgeon opts for immediate definitive fixation or a staged approach. Ultimately, the trend in specialist centers is toward an orthoplastic approach, where integrated teams schedule definitive fixation as an urgent elective procedure during normal working hours to ensure the availability of senior staff and full equipment [5].

Section 4: Discussion (<1000 words)

The included studies demonstrate a substantial shift toward the orthoplastic treatment paradigm, characterized by early definitive internal fixation combined with timely soft-tissue reconstruction. Across a range of injury patterns, this integrated approach has consistently achieved high limb-salvage rates, acceptable infection rates, and satisfactory functional outcomes.

Limb salvage rates were remarkably high when modern orthoplastic protocols were applied. In severe forearm fractures managed with early internal fixation and free-flap coverage, limb salvage reached 100%. Similarly, complex distal tibial fractures treated with simultaneous internal fixation and distally based sural flap (DBSF) reconstruction demonstrated complete flap and limb survival. Larger series of Gustilo type IIIB tibial shaft fractures reported overall limb-salvage rates of approximately 93%, with delayed amputations occurring only in a minority of patients because

of complications such as chronic pain, pressure ulcers, or persistent functional impairment. These findings suggest that even severe open fractures can often be successfully reconstructed when treated within a coordinated multidisciplinary framework.

A central observation across the literature is that primary internal fixation does not appear to increase the risk of infection when combined with meticulous debridement and appropriate soft-tissue management. Historical comparisons demonstrated lower deep infection rates following primary internal fixation than after conservative treatment strategies, with reported rates of 13.1% and 22.6%, respectively. The mechanical stability provided by internal fixation facilitates wound care, reduces dead space formation, and promotes soft-tissue healing. Contemporary "fix-and-flap" protocols have further improved outcomes, with reported deep infection rates ranging from 0% in upper-extremity injuries to approximately 6%–9% in severe tibial fractures. Importantly, studies from specialist trauma centers have shown that flap failures and most deep infections occur predominantly in patients referred from other institutions rather than in those receiving definitive treatment at the initial presenting center, emphasizing the importance of early specialist involvement.

The findings also challenge the traditional "six-hour rule" for emergency debridement. Several studies failed to demonstrate a significant association between debridement performed before or after six hours and subsequent infection rates. Instead, outcomes appear to be more strongly influenced by the quality of the initial debridement and the prompt administration of systemic antibiotics, ideally within the first hour after injury. Reflecting this evolving evidence base, current United Kingdom guidelines advocate definitive fixation and soft-tissue coverage within 72 hours whenever feasible. Adoption of this strategy has been associated with stable deep infection rates of approximately 7% in national trauma systems.

Despite advances in fixation techniques and soft-tissue reconstruction, fracture healing remains prolonged in many high-energy open injuries. Reported mean union times ranged from approximately 23 weeks in distal tibial fractures to 28–41 weeks in tibial shaft fractures. Furthermore, between 17% and 34% of patients required additional interventions, including bone grafting or exchange nailing, to achieve complete union. Forearm fractures generally demonstrated lower rates of delayed union and nonunion, with reported nonunion rates of approximately 15%, likely reflecting the more favorable vascular environment of the upper extremity.

Functional outcomes were generally favorable, although many patients did not regain their preinjury level of function. In forearm fractures, approximately two-thirds of patients achieved excellent or good results according to the Anderson classification. For tibial injuries, modified Enneking scores averaged approximately 74%–75% of normal limb function. Nevertheless, residual disability remained common, particularly

after lower-extremity injuries. Long-term complications such as ankle stiffness, persistent limping, and activity limitations were frequently reported. Despite these impairments, patient satisfaction was consistently high. Many patients expressed a strong preference for limb preservation over amputation, even when objective measures of physical function remained below population norms. Return-to-work rates varied between 41% and 67%, although some individuals required occupational modifications or transition to less physically demanding roles.

Several studies also highlighted the success of specific reconstructive strategies. The distally based sural flap emerged as a reliable and technically straightforward option for distal tibial soft-tissue defects. In parallel, emerging evidence suggests that Continuous Local Antibiotic Perfusion (CLAP) techniques, including intramedullary antibiotic perfusion (iMAP) and intra-soft tissue antibiotic perfusion (iSAP), may offer promising adjunctive treatment options for fracture-related infection while allowing retention of stable internal fixation. Although clinical experience remains limited, these approaches represent an important area of ongoing investigation.

Overall, the available evidence strongly supports the orthoplastic model of care. The close collaboration of orthopedic trauma and plastic surgery teams facilitates early definitive fixation, timely soft-tissue coverage, and coordinated postoperative management. This integrated approach has been associated with improved limb-salvage rates, acceptable infection control, reduced morbidity, and optimized long-term function.

Section 5: Risk of bias of included studies
LOW/ MODERATE/ HIGH

Moderate

Section 5: Response/Recommendation (1-2 lines as a conclusion and recommendation statement for the question)

Well-defined criteria for performing definitive internal fixation in open fractures primarily depend on the fracture configuration (e.g. bone loss), the degree of wound contamination (e.g. agricultural, marine, or sewage debris), and the ability to achieve stable soft-tissue coverage. Regarding the duration from the time of injury, current evidence emphasizes a 72-hour window for definitive "fix and flap" procedures. The presence of comorbidities and the hemodynamic conditions also dictate the timing and type of fixation.

Section 6: Level/ strength of Evidence:
LOW/ MODERATE/ HIGH with justification.

Based on the number of studies, risk of bias, study design, sample size, and key outcomes.

MODERATE: The scientific literature in this field is composed of retrospective cohort studies rather than high-level RCTs.

(Kindly add citations wherever necessary and reference list at the end)

1. Luo J, Zhou M, Lin F, Wang J, Rui Y (2023) Clinical effectiveness of early internal fixation combined with free flap technique in the treatment of Gustilo IIIB open forearm fracture. Orthop Traumatol Surg Res 109 (5):103346. doi:10.1016/j.otsr.2022.103346
2. Gopal S, Giannoudis PV, Murray A, Matthews SJ, Smith RM (2004) The functional outcome of severe, open tibial fractures managed with early fixation and flap coverage. J Bone Joint Surg Br 86 (6):861-867. doi:10.1302/0301-620x.86b6.13400
3. Jitprapaikulsarn S, Sukha K, Patamamongkonchai C, Gromprasit A, Thremthakanpon W (2021) Concurrent internal fixation and soft tissue reconstruction by distally based sural flap: a practicable scheme for complex distal tibial fractures. Eur J Orthop Surg Traumatol 31 (4):711-718. doi:10.1007/s00590-020-02827-8
4. Naique SB, Pearse M, Nanchahal J (2006) Management of severe open tibial fractures: the need for combined orthopaedic and plastic surgical treatment in specialist centres. J Bone Joint Surg Br 88 (3):351-357. doi:10.1302/0301-620X.88B3.17120
5. Minehara H, Maruo A, Amadei R, Contini A, Braile A, Kelly M, Jenner L, Schemitsch GW, Schemitsch EH, Miclau T, 3rd (2023) Open fractures: Current treatment perspective. OTA Int 6 (3 Suppl):e240. doi:10.1097/OI9.0000000000000240
6. Varma BP, Rao YP (1974) An evaluation of the results of primary internal fixation in the treatment of open fractures. Injury 6 (1):22-27. doi:10.1016/0020-1383(74)90164-8