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Is primary autologous bone grafting recommended for critical bone defects following adequate debridement and stabilisation?

Background

Bone loss occurs in about 11.4% of all open fractures, and most frequently in Gustilo Type IIIA and IIIB fractures.¹ A critical bone defect is defined as one that will not heal spontaneously after surgical fixation and thus requires an additional intervention.^{1,2} Autologous bone grafts- both cancellous and cortical- stand as viable options in attempting to close the gap and establish union.³ However, the timing of the graft is ambiguously spread throughout literature. Concerns pertaining to contamination, infection, and graft resorption have always existed, due to which delayed grafting strategies were traditionally employed. Recent evidence does suggest that primary autologous bone grafting at the index surgery, following thorough debridement and primary soft tissue cover, achieves faster union rates⁴⁻¹⁰. Despite the evidence, the time- honored staged autologous bone grafting is advocated by many surgeons. Our review attempts to achieve a consensus regarding primary autologous bone grafting for critical sized bone defects in open fractures- with a focus on union and infection rates, along with functional outcomes.

Data Extraction Table

Author, Year of publication, Country	Study Design	Sample size	Study Population	Groups compared	Results/ Comments
Halawi et.al , USA, 2015 ⁴	Narrative Review				Primary Bone grafting can be done at the time of closure in type I and II open injuries, but should be delayed until the wound has healed in type III fractures.

Hatashita et.al , Japan, 2019 ¹¹	Retrospective observational study	7 patients	Patients undergoing Masquelet technique for open fractures with bone defects	Evaluated post surgical complications like deep infections, graft resorption, time to union	Deep Infections (14%), Bone resorption (0%), 2 patients needed additional procedures for bone union
Egol et.al , USA, 2015 ¹²	Narrative Review				Primary bone graft at index surgery has negative effects due to vasoconstriction, hypoxia and acidosis. Induced membrane technique provides higher levels of biological activity for graft incorporation
Kesemenli et.al , Turkey, 2004 ⁵	Retrospective observational study	20 patients	Patients presenting with Type III Gustilo open fractures, underwent primary autogenous bone grafting at index surgery	Followed up with the criteria- wound status after various methods of skin coverage, time to fixator removal, time to union, and infection rate	Delayed primary closure (4), Myocutaneous flap (2), Split skin grafting (14). Mean time to fixator removal- 21 weeks, mean time to union- 28 weeks. 5% rate of delayed union, 5% rate of infection. Primary prophylactic bone grafting reduced rate of delayed union and does not increase infection rate
Blick et.al , USA, 1989 ¹³	Retrospective observational study	53 patients	Patients presenting with high energy tibia fractures and undergoing bone grafting at 8-10 weeks.	Compared with a historical control group that did not receive any bone graft	Mean reduction in time to union was 11.7 weeks, incidence of osteomyelitis was 1.9%. Recommend bone grafting after two weeks if closure was achieved by delayed primary closure/ SSG? local rotation flaps. bone graft after 6 weeks following a free flap.
Zalavras et.al , USA,, 2005 ¹⁴	Narrative Review				The preferred timing for bone grafting ranges in the literature from 2 to 6 weeks after soft tissue coverage to reduce the risk of infection and allow restoration of the soft tissue envelope.
Adamczyk et.al , Canada, 2020 ¹⁵	Narrative Review				step-wise, multidisciplinary approach, rather than immediate primary grafting in most severe open injuries.

Kanakaris et.al , UK, 2025 ¹⁶	Narrative Review				fixation of type-1 defects (≤ 20 mm) can be followed by secondary bone grafting if spontaneous healing does not occur. bone loss >20 mm are preferred for the induced membrane technique or bone transport
Yazar et.al , China, 2004 ⁶	Retrospective observational study	49 patients	62 traumatic lower extremity fractures treated with debridement and one- stage bone and soft tissue coverage reconstruction using vascularized bone grafts		Primary union rate 88.5%, Overall union rate 96.7%. Mean primary union time 6.9 months, mean overall union time 8;5 months. Stress fracture rate 11.5%. Post op infection rate 7.9%, osteomyelitis 3.2%, 1 patient amputation. Complete flap survival 88.9%, total flap loss 3.2%, partial flap loss 7.9%.
Ruta et.al , USA, 2014 ⁷	Narrative Review		Reviewed articles on primary autologous bone grafting in open fractures of the hand with segmental bone loss		Primary autologous bone grafting can be safely and effectively performed in open fractures with segmental loss, provided that is combined with radical aggressive debridement, stable fixation and. immediate soft tissue coverage at the index surgery. no increase in infection risk, reduced morbidity, decreases hospitalization and number of surgeries, earlier mobilization and return to work, achieves high union rates.
McMurtie et.al, USA, 2021 ⁸	Retrospective observational study	12 patients	Both open and closed talar neck fractures with gap >5 mm in sagittal plane and more than 1/3rd of the width of talar neck in the coronal plane- treated with	Compared on the basis of open vs closed, Hawkins type, reduction quality, union rates, and occurrence of AVN	33% open fractures, total union rate 92%, AVN rate 92%, malunion rate 8%. Deep infection rate 0%.

			primary autologous bone grafting		
Fakoor et.al , Iran, 2013 ¹⁷	Prospective comparative study	144 patients	Patients with any grade of open tibial fractures	Compared groups that underwent bone grafting at 3 weeks and 6 weeks	3 week grafting union time 14.24 +/- 4.4 weeks. 6 week grafting union time 16.4 +/- 5.4 weeks. Reduction in healing time was 2.2 weeks earlier in the 3 week grafting group- statistically significant. no increased rates of infection in either group.
Tropet et.al , France, 1999 ⁹	Retrospective observational study	18 patients	Gustilo IIIB open fractures treated with Cancellous iliac crest graft along with soft tissue reconstruction at the index procedure.	Evaluated primary union rates, time to union, infection rates, flap survival rates, return to work, malunion rates and need for amputation	Primary union rates- 72.2%, 2 non unions, 3 infections, mean time to clinical union 6.5 months, mean time to radiographic union 9 months, 13 patients (72.2%) returned to previous work, moderate malunion in 6 cases, No amputations done. Primary bone grafting reduced time to healing, number of operations with improved functional outcomes.
Francel, USA, 1994 ¹⁸	Retrospective observational study	65 patients	Gustilo IIIB open fractures treated with Cancellous iliac crest graft along with soft tissue reconstruction at the index procedure.	evaluated the return- to-work rates using predictors like early bone union, stable skeletal reconstruction, successful soft tissue coverage, fewer secondary procedures, and early ambulation	Re employment after limb salvage- 69%, return to previous job level- 51%
Dheenadhayalan et.al , India, 2023 ¹⁹	Narrative Review				Timing of grafting should be individualized based on contamination, soft tissue condition, vascularity, and defect size. For large segmental defects, vascularized grafts, Masquelet

					technique, bone transport, and staged reconstruction are better suited.
Gupta et.al , India, 2019 ¹⁰	Prospective case series	21 patients	Gustilo IIIA and IIIB open tibial fractures treated with debridement and fracture fixation with immediate bone grafting.	Analyzed for time to fracture union, pin tract infection, wound infection, flap complications, and delayed or non union.	mean time to union- 22 weeks. 5% deep infection, 5% showed delayed union. 20/21 united without any major complication. Inferred that primary autologous bone grafting along with early wound coverage and external fixation can be employed in grade IIIB open tibial fractures with satisfactory union, and low rates of deep infection.
Davirov et.al , Russia, 2022 ²⁰	Case Report	1 patient	Gustilo IIIB open comminuted distal humerus fracture with 22cm humeral bone defect after RTA, underwent staged reconstruction with autologous fibular strut graft	Analyzed for elbow function, graft rejection and infection at 2 years and 4 years	Limb length preserved, fibrous ankylosis of the elbow, all functions regained, back to work at 4 year follow up.
Tropet et.al , France, 2001 ²¹	Retrospective observational study	5 patients	Gustilo IIIB open tibial fractures with bone loss treated with immediate debridement, intramedullary nailing, primary iliac crest cancellous bone grafting and free muscle flap coverage	Evaluated for time to union, infection rates, functional ability, incidence of non unions	mean time to union 7.6 months, 1 superficial infection, no osteitis, 0 deep infections, 0 non unions, 0 deformities, mean time to full weight bearing 5 months, excellent functional recovery
Bali, et.al , India, 2010 ²²	Case Report	1 patient	AO C3 Gustilo IIIB open fracture following RTA, treated with debridement, bicolumnar plating of humerus, primary iliac crest strut graft	Evaluated for time to union, elbow ROM, malunion, joint instability, skin appearance , activity level	Fracture union at 14 months, ROM 30-110 degree, full supination and pronation, no varus/ valgus/ good wound status, able to perform daily activities similar to prior-to-injury levels. Mayo Elbow Performance Score- 92

			and primary wound closure.		(excellent)
Ma et.al , China, 2022 ²³	Retrospective observational study	15 patients	Gustilo IIIA and IIIB open tibio- fibular fractures with bone defects treated with immediate debridement, iliac crest bone grafts and internal fixation followed by split skin graft over the skin defects.	Observed for extended hospitalization, delayed wound healing, delayed bone union, functional recovery using the LEFS	Mean fracture union time 18.5 weeks, length of hospital stay 25.1+/- 7.6 days, mean wound healing time 12.2+/- 2.0 days. 0 incidence of deep infection and osteomyelitis. Mean follow up period 22.8 months. Mean LEFS at final follow up 70.
Saint-Cyr et.al , USA, 2006 ²⁴	Retrospective observational study	12 patients	Open hand fractures, with segmental bone loss in 7 patients, multilevel fractures with intra articular involvement in 4 patients- treated with primary debridement, bone grafting and internal fixation along with primary wound closure.	Evaluated for union rates, time to union, infections, rate of return to employment	Final union rate 92%, Mean time to union 18 weeks, infection rate 0%, Mean time to return to work 5 months 21 days, rate of return to employment 100%
Stahl et.al , Israel, 2009 ²⁵	Retrospective observational study	3 patients	Open hand fractures with segmental bone loss, presented within 4-6 hours after injury, treated with debridement, primary internal fixation, immediate autologous corticocancellous bone grafting, and soft tissue reconstruction	Followed up for fracture union, infection, functional recovery of the hand, cosmetic deformity, and need for additional procedures	Radiographic union- 100%, graft incorporation 100%, infection rate 0%, Excellent/ good functional result 100%. Recommend immediate autologous bone grafting only if full debridement is achieved with abundant blood supply. If not achieved, bone grafting to be done as a delayed procedure.

Mitchell et.al , UK, 2010 ²⁶	Retrospective observational study	31 open distal femur fractures in 29 patients with bone loss	Open distal femur fractures with bone loss treated with early aggressive debridement, stable skeletal fixation, early soft tissue coverage and Secondary autologous bone graft	Evaluated for mean union time, need for secondary bone grafting, knee stiffness, malunion, limb length discrepancy, infections, non unions	All metaphyseal and wedge defects healed without bone grafting. Segmental defects required staged bone grafting. Study does not support primary autologous bone grafting in open fractures
Dugan et.al , USA, 2013 ²⁷	Retrospective observational study	14 patients with 15 fractures	Patients of polytrauma with AO C2/C3 Gustilo IIIA/IIIB open fractures with bone defects treated with debridement, primary internal fixation, soft tissue cover, and delayed bone grafting, BMP supplementation and medial column plating after improved general condition of the patient	Outcomes of union rate, mean time to union, deep infection rate, coronal plane deformities, knee stiffness were evaluated	Union rate 100%, mean time to union after grafting 4 months, deep infection rate 0%, mean coronal plane alignment change 0.46degrees, with common complaint of knee stiffness. Study is strongly in favour of delayed biologic reconstruction after early mechanical stabilization in open fractures with bone loss.

Results

Overall literature shows heterogenous opinions regarding primary autologous bone grafting in open fractures with critical sized bone defects. Most of the evidence was gathered from Case reports/ series as well as review articles. Impressions vary based on fracture severity, contamination, soft tissue status, and extent of bone loss. According to a majority of the research reporting directing clinical outcomes, high union rates can occur in primary autologous bone grafting, provided 4 criteria are met: thorough radical debridement, stable skeletal fixation, early or immediate soft tissue coverage, and careful patient selection.

Tropet et al.⁹ demonstrated a primary union rate of 72%, overall good functional outcomes, and suggested that primary grafting reduced healing time and the number of secondary procedures. Ruta et al. ⁷ concluded that primary autologous grafting in open fractures with segmental bone loss is safe and

effective when combined with aggressive debridement, stable fixation, and immediate soft-tissue coverage. Kesemenli et al.⁵ found that prophylactic primary bone grafting reduced delayed union without increasing infection rates (5% infection). Gupta et al.¹⁰ reported satisfactory outcomes in Grade IIIB tibial fractures treated with primary grafting, external fixation, and early flap coverage, achieving union in 20 of 21 patients with only 5% deep infection. Stahl et al.²⁵ reported 100% union and graft incorporation with no infections, but emphasized that primary grafting should only be undertaken when complete debridement and adequate vascularity are achieved.

Yet, there is still a substantial body of evidence that is prudent about primary autologous bone grafting. Historical studies such as Blick et al.¹³ recommended grafting approximately 2 weeks after injury when delayed primary closure or skin grafting had been achieved, and even later after free-flap coverage. More recently, Zalavras et al.¹⁴ advocated grafting 2–6 weeks after soft-tissue coverage to reduce infection risk and restore the biological environment. Mitchell et al.²⁶ observed that many metaphyseal and wedge defects healed without grafting, while segmental defects required staged reconstruction, providing little support for routine primary grafting. Dugan et al.²⁷ strongly favoured delayed biological reconstruction after early stabilization, reporting excellent outcomes with staged management. Halawi et al.⁴ recommended grafting at closure for Gustilo I and II injuries but delaying grafting in type III fractures until soft tissues have healed. Egol et al.¹² argued that the inflammatory environment present at the index surgery (vasoconstriction, hypoxia, acidosis) may impair graft incorporation and that induced membrane techniques provide a more favourable biological milieu. Adamczyk et al.¹⁵ supported a staged multidisciplinary approach rather than immediate grafting in severe open injuries.

Discussion

Biology and biomechanical stability are crucial for any fracture to heal. The concept of using bone grafts for critical sized defects in the bone has been a part of the general treatment strategies of fractures. Autologous iliac crest bone grafts have the best potential for osteogenic, osteoconductive, and osteoinductive properties.²⁸ However, the use of bone grafts is challenging in open fractures with bone loss. Three options present themselves to surgeons: primary bone grafting (at the time of the index surgery), subacute bone grafting (performed at a second surgery but still in the acute phase of treatment), or delayed bone grafting (weeks after a primary surgery). There is a sense of caution with primarily grafting the bone defects in open fractures since the contamination itself could convert the graft into a nidus for infection.¹²

The biological status of the injured soft tissues is partly responsible for the healing trajectory of fractures. In the acute phase of trauma, biological studies have shown that there is relative hypoxia, acidosis, inflammatory cytokine release, and compromised perfusion in the soft tissues surrounding the fracture. Advocates of staged reconstruction state that in a two- stage procedure using the induced membrane technique the vascularized induced membrane, growth factor accumulation, and improved soft tissue condition may provide a more favourable biological environment to allow bone graft incorporation and ultimately, union. ^{2,3,11,13–17,26,27,29}

More recently, this notion has been challenged by advancements in debridement, fixation, antibiotic protocols, and soft tissue coverage. Patients' demands and expectations for quality of life during the treatment process, as well as for functional outcomes, are continuously increasing along with the growth of the economy and society. Primary autologous bone grafting helps address this need and thus significantly reduces the physiological and psychological traumatic stress response of the patient, and promotes faster postoperative rehabilitation.³⁰ Proponents of primary autologous bone grafting argue that it offers the advantage of reduced cost, fewer surgeries, early achievement of range of motion and function of the limb, all without increasing the risk of infection. ^{5–7,9,10,25,31}

Risk of bias in the included studies: Moderate- High

Recommendation proposed for consensus

Primary autologous bone grafting for critical sized defects in open fractures is highly dependent on proper patient selection. If delayed, earlier grafting (around 2-6 weeks) is preferable to prolonged delay.

Level of evidence: Most of the available evidence consists of Level IV studies- predominantly retrospective case series. There is discrepancy in fracture type, debridement strategies, level of contamination encountered, fixation methods used, timing of soft tissue cover, and the volume of bone graft used. This leads to a moderate- high risk of bias and hence the level of evidence is low.

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