Is bone transport (distraction osteogenesis) performed underneath a flap a safe and effective primary management strategy for bone defects?

Section 1: Background (<300 words)

Segmental bone loss in open tibial fractures is usually associated with contamination, devitalized bone, exposed tendons or neurovascular structures, and major soft-tissue loss. Management requires an orthoplastic approach that includes radical debridement, skeletal stabilization, and early vascularized soft-tissue coverage. Traditionally, limbs with critical bony defects were managed by debridement, resection, and shortening to permit primary soft-tissue closure. More recently, combining free tissue transfer with bone transport has allowed maintenance of limb length while avoiding many complications of traditional techniques and aiming to restore function.(1)

Bone transport using distraction osteogenesis reconstructs segmental defects biologically, while flap coverage restores a vascularized soft-tissue envelope. Together, these methods can address large bone and soft-tissue defects: flap coverage maintains limb length from the outset, improves vascularity for fracture healing, provides healthy tissue under which distraction osteogenesis can occur(2), and facilitates bone grafting or other subsequent procedures at the docking site (3).

However, iatrogenic soft-tissue damage remains a major concern, especially in Gustilo-Anderson type III fractures. Surgeons must therefore choose a fixation and reconstruction strategy that protects the flap, its pedicle, and the surrounding soft tissues. The specific clinical question is whether bone transport performed beneath a flap is safe and effective as a primary reconstructive strategy for bone defects. At present, there remains limited evidence guiding the optimal combination of fixation method and reconstructive technique.

Section 2: Data extraction table

S.no	Author, year, Country	Study design	Sample size	Study population	Intervention	Results	Other comments
1	Hosny & Fadel, 2003, Egypt(4)	Retrospective case series	34 treated; 30 evaluated. Bone-loss subgroup: 4 cases	Open tibial diaphyseal fractures; bone loss in 4 fractures: 3 IIIB and 1 IIIC	Ilizarov used as initial/definitive fixation. Corticotomy was performed for defects >4 cm; distraction was started after 10 days at 1 mm/day. Soft tissue was managed by delayed closure, Z-plasty, STSG, pedicled flaps, delayed flaps, and Ilizarov-assisted skin traction.	All fractures united. In the bone-loss cases, mean bone loss was 8.25 cm, mean regenerate length was 6.5 cm, mean bone transport duration was 8.8 months, and mean Ilizarov fixation duration was 11.1 months.	There were 2 primary flaps, 2 delayed flaps, and 4 skin-traction procedures. Delayed flaps provided acceptable coverage, and skin traction created adequate fasciocutaneous coverage in 4 cases. Bone transport after arterial repair or skin-flap procedures caused no major problems. One hematoma occurred during bone transport under a delayed muscle flap and was aspirated. Skin release was required in 4 patients.
2	Repo et al., 2016, Finland(5)	Retrospective review + cross-sectional long-term outcome study	10 patients with open fractures and bone transport	Traumatic compound tibial defects treated with microvascular latissimus dorsi flap + Ilizarov distraction osteogenesis. Mean age was 33 years. Soft-tissue defects ranged from 4 × 6 cm to 10 × 30	Microvascular LD muscle or musculocutaneous flap followed by Ilizarov bone transport or late tibial lengthening. Bone-transport corticotomy was performed either simultaneously with the flap or later, with a median interval of 23 days after flap reconstruction.	Mean clinical follow-up was 6.6 years. Mean external fixation time was 178 days, with a fixation index of 54 days/cm. In the bone-transport subgroup, mean time to full weight-bearing was 14.3	Flap complications included thrombosis in 2, infection in 1, fistulation in 2, and partial flap necrosis in 1. Flap reoperations included revision in 4, re-anastomosis in 2, vein grafting in 1, and debulking in 1. The authors specifically stated that no anastomotic flap complication occurred during or after distraction, and that

S.no	Author, year, Country	Study design	Sample size	Study population	Intervention	Results	Other comments
				cm; bone defects ranged from 4.5 to 12 cm.	The distraction area was selected to avoid direct stretching of the pedicle.	months, and mean time to complete radiological union was 16.0 months. Median new bone in the transport group was 4 cm (range, 2–12 cm). Bony union was achieved in all cases, and there was no secondary amputation. LEFS was 59 in the bone-transport group and 62 in the lengthening group. Of 13 patients with available work status, 12 returned to work.	segmental tibial transport/lengthening did not compromise the microvascular muscle flap. Docking/bone complications in the bone-transport subgroup included pin-site infection in 3, delayed union in 3, osteomyelitis in 2, pseudoarthrosis in 2, refracture in 4, and malunion in 3. Bone grafting for transport was required in 5 cases.
3	Hohmann et al., 2017, South Africa(6)	Retrospective protocol-based case series, Level IV	32 total; acute open tibial fracture with bone-loss subgroup: 12	Complex high-energy tibial trauma, including acute open fractures, infected non-unions, and aseptic/non-infected non-unions	"Road to Union" staged protocol: debridement + PMMA spacer + temporary external fixation → flap cover → definitive circular/hexapod frame → spacer removal + corticotomy → distraction osteogenesis.	Mean bone defect was 66 ± 32 mm. Union was achieved in 29/32 patients (91%). Total EFT was 42.5 ± 14.8 weeks; EFI was 51.9 ± 25.3 days/cm; and DCI was 48.3 ± 21 days/cm. Pin-site infection occurred in 11 patients, persistent non-union in 3, and delayed amputation in 3.	Soft-tissue cover was generally performed within 48–72 h by a plastic surgeon. ALT flaps were used for smaller defects and latissimus dorsi flaps for larger defects. A latency period was allowed for flap maturation before definitive bone transport. During PMMA spacer removal, the flap was elevated through a mini-open approach from the side opposite the vascular pedicle to avoid pedicle injury.
4	van Niekerk et al., 2017, South Africa(7)	Retrospective comparative cohort, Level III	24 total: 12 acute grade III open tibial fractures and 12 infected tibial non-unions	Segmental tibial bone loss; acute trauma group had a mean defect of 82 ± 36 mm	Acute open fracture group versus infected non-union group; both groups were treated with circular external fixation + antibiotic PMMA spacer + flap cover + distraction osteogenesis.	The trauma group had a better EFI than the infected non-union group (37.3 ± 9.1 days/cm vs 56.6 ± 14.5 days/cm). Pin-tract infection occurred in 7/24 patients. Non-union occurred in 2 patients, both of whom were eventually treated with amputation.	In the acute trauma group, soft-tissue reconstruction was performed at a mean of 1.2 ± 1.2 days. Coverage was by ALT flap or latissimus dorsi free flap. At the second stage, the PMMA spacer was removed by mini-open elevation of the flap opposite the vascular pedicle. The authors stated that the induced membrane/spacer can act as a conduit for bone transport and prevent soft-tissue impingement.
5	Elbeshry & Alabd, 2019/2020, Egypt(8)	Clinical case series	8 patients	Gustilo IIIB open tibial fractures with massive bone and soft-tissue loss; all were middle-third tibial defects	Initial debridement + primary LRS uniplanar external fixator. Second-stage rotational medial head gastrocnemius myocutaneous flap + STSG and osteotomy for segment transfer were performed within 10–14 days.	Full union was achieved in all patients. Mean union time was 374 days, and EFI was 45.3 days/cm. Docking-site iliac grafting was required in 5/8 patients. No significant malalignment occurred, and significant shortening occurred in only 1 patient. Docking-site freshening and cancellous grafting were performed in 5/8 patients when there was no radiological union after 6 weeks of bone contact.	All patients underwent second-look debridement within 1 week before flap/osteotomy. There was no flap-coverage infection and no infection at the myocutaneous flap or osteotomy site. The authors emphasized that LRS is lighter and less bulky than Ilizarov, allowing easier soft-tissue access/coverage and plastic-surgical intervention. Pins were inserted perpendicular to the tibial axis with care to maintain mechanical alignment.
6	Patel et al., 2021, UK(9)	Large retrospective case series	74 patients; 75 type III open tibial fractures	Adult Gustilo III open tibial shaft fractures: 26 IIIA, 47 IIIB, and 2 IIIC. Bone defects were present in 33 cases, with a mean defect of 5.4 cm.	IMN, Taylor Spatial Frame, or Masquelet technique was used depending on fracture and soft-tissue status. TSF was commonly used for severe IIIB/C injuries; when required, bone	Infection occurred in 6.7%, non-union in 4%, and refracture in 2.7%. Mean union time was 38.6 weeks for TSF. Limb salvage was 98.7%. Two patients	Plastic surgeons were involved from admission. Soft-tissue cover was performed at a mean of 9.3 days on a combined orthoplastic list. Coverage included 60 free flaps, 10 local flaps, and 5 SSG; free flaps included gracilis,

S.no	Author, year, Country	Study design	Sample size	Study population	Intervention	Results	Other comments
					transport was started on day 8 after corticotomy.	sustained atraumatic refracture at the docking site after TSF removal; both were successfully treated with autologous bone graft plus IM nail or reapplication of TSF.	latissimus dorsi, and ALT. Two patients had traumatic posterior tibial artery injury requiring bypass.
7	Dheenadhayalan et al., 2022, India(10)	Retrospective cohort, Level III	35 patients	Open tibial fractures with primary bone loss >4 cm requiring bone transport	Primary LRS using a temporary spacer rod and plate technique to minimize docking malalignment. Soft-tissue cover was performed within 72 h when primary closure was not possible; corticotomy was performed after soft-tissue cover.	Mean regenerate length was 8.4 ± 3.45 cm. Functional ASAMI results were excellent in 13, good in 19, fair in 1, and poor in 2. Mean EFI was 43.36 ± 27.74 days/cm. Delayed union occurred in 17 patients, pin-tract infection in 6, and deep infection in 3.	Coverage included SSG in 7, local flap in 7, free flap in 16, and cross-leg flap in 5. Skin invagination occurred in 4 patients during lengthening/docking and was treated by excision.
8	Necula et al., 2024, Romania(1)	Systematic review; secondary evidence	14 studies; 283 participants	Distal tibia high-energy/open fractures treated with circular external fixation plus reconstructive methods	Review of circular external fixation combined with flap/soft-tissue reconstruction	Bone loss ranged from 0.7 to 18.2 cm, and fixation duration ranged from 4 to 22.74 months. Complete flap loss occurred in only 3/283 patients. Non-union was low, and union was ultimately achieved after reintervention.	There were 80 free flaps and 73 pedicled flaps among 249 reconstructive procedures. Only 8/230 had partial or complete flap non-survival. Partial necrosis was mostly managed conservatively, and 3 patients required additional flap procedures. The review concluded that a circular fixator can be combined with a flap because it does not damage the pedicle and stabilizes tissues around the flap. K-wires/small-diameter wires may minimize vascular disruption.
9	Li et al., 2021, China(11)	Retrospective clinical case series	40 patients	Severe composite tibial bone and soft-tissue defects; all Gustilo IIIB. Age 16–65 years; 27 male and 13 female patients. Mechanism: vehicle accident 26, fall 9, crushing injury 5. Tibial defect 4–18 cm, mean 8.25 cm. Soft-tissue defect 7.5 × 5 cm to 35 × 30 cm. Defect location: middle tibia 18, distal 12, proximal 10.	Early debridement + temporary simple external fixation + NPWT/VSD, followed by replacement with a transport external fixator. For proximal/distal wounds, temporary external fixation was placed across the joint to avoid pins through the exposed bone surface. Tibial osteotomy/bone transport and free flap transplantation were performed simultaneously or consecutively. Bone sliding began 1 week post-operatively at 0.5–1 mm/day.	All 40 wounds healed after flap reconstruction. Mean follow-up was 28.2 months. Fixator type: unilateral 28, circular 9, combined 3. Mean external fixation time was 12.83 ± 2.85 months, and EFI was 1.55 months/cm. ASAMI functional outcomes were excellent in 24, good in 10, moderate in 4, and poor in 2; excellent/good = 85%. Nonunion occurred in 8 and was treated with iliac bone graft. Refracture occurred in 2, mechanical-axis deviation in 10, joint stiffness/foot drop/claw toe in 8, shortening <2 cm in 4, and shortening >3 cm in 1.	Free flaps were used in all cases: ALT flap in 33, latissimus dorsi flap in 5, and thoraco-umbilical flap in 2. Flap crisis occurred in 3/40 and was treated by vascular exploration; 1 flap survived completely and 2 developed slight necrosis that healed after debridement/grafting/dressing. Hydrops or fat liquefaction around the flap occurred in 5 and healed with dressing. No complete flap loss was reported.
10	Stoneburner et al., 2020, USA(12)	Systematic review + retrospective 3-case institutional series	**4 studies, 32 patients**	Acute traumatic extremity injuries managed with flap + distraction osteogenesis	Bone transport with soft-tissue reconstruction. Ilizarov frame used in most studies. Flap type, timing of flap/frame, bone defect, distraction details, flap complications, nonunion, malunion, infection, reoperation,	Flap type, timing of flap/frame, bone defect, distraction details, flap complications, nonunion, malunion, infection, reoperation, amputation, weight-bearing and success rate.	Authors state that free flap coverage provides healthy vascularized soft tissue under which distraction osteogenesis can occur. Pins through the flap may be safe, but their path must avoid the pedicle; careful ortho-plastic planning is essential

S.no	Author, year, Country	Study design	Sample size	Study population	Intervention	Results	Other comments
					amputation, weight-bearing and success rate.		

Section 3: Results summary

Across the included clinical series, bone transport under or after flap coverage generally achieved high union and limb salvage rates, although with a substantial treatment burden. Union was reported in all patients in several case series, including Elbeshry et al.(8), Lowenberg et al(3)., and Li et al.l(11), while Hohmann et al.(6) reported 91% union. Limb salvage was usually >90%, and functional recovery was frequently good or excellent by ASAMI/Paley criteria or ambulation-based outcomes.

With respect to flap safety, the evidence is reassuring. Most series reported complete flap survival or very low rates of complete flap loss. Li et al. reported flap crisis in 3/40 patients: one flap survived completely after exploration, while two developed slight necrosis that healed after debridement, grafting, or dressing. No complete flap loss was reported. Repo et al. reported thrombosis in 2 patients, infection, fistulation, and one partial flap necrosis, but specifically noted that there was no anastomotic flap complication during or after distraction and that transport/lengthening did not compromise the LD flap.(5) Lowenberg et al. reported 1 flap loss among 35 flaps.(3) Yuan-jian Wu et al. reported no disruption of the pedicle from device placement or subsequent distraction.(13) Necula's systematic review also supports flap safety, reporting complete flap loss in only 3/283 patients and partial or complete flap non-survival in 8/230 reconstructed cases.(1)

The main complications were usually not flap loss, but pin-tract infection, docking-site nonunion or delayed union, malalignment or axis deviation, joint stiffness, soft-tissue invagination, recurrent infection or osteomyelitis in selected cases, and need for secondary procedures. Docking-site bone grafting or freshening was common and should often be considered an expected part of treatment rather than a failure.

Section 4: Discussion

The included studies support that bone transport can be safely performed beneath or after flap coverage, provided it is part of a planned orthoplastic strategy.(12) The combined use of flap coverage and distraction osteogenesis is biologically logical: the flap provides vascularized coverage, protects exposed bone, tendons and neurovascular structures, improves the local environment for union, creates a soft-tissue envelope beneath which transport can occur, and facilitates later procedures such as docking-site grafting. A systematic review by Stoneburner et al. noted that flap coverage combined with bone transport helps maintain limb length, improves vascularity for fracture healing, and facilitates later docking-site procedures.s(12)

In the included studies, complete flap loss was rare. Minor flap complications were more frequent and included superficial edge necrosis, venous crisis or thrombosis, fistulation, hydrops or fat liquefaction, and occasional need for re-exploration or re-anastomosis. These events were usually salvageable. In a systematic review by Necula et al., the flap survival rate was 83.33%, indicating that reconstructive surgery combined with Ilizarov external fixation is effective for managing these injuries.(1) Complete flap loss occurred in only 3/283 patients (1.06%). The authors suggested that the small diameter of Kirschner wires minimizes disruption of vascularity in the surrounding soft tissue, so the covering tissue is not significantly affected by the osteosynthesis method.(14) The more consistent and clinically important issues were not flap failure, but the prolonged reconstructive course, docking-site nonunion, pin-site infection, stiffness, and repeated procedures, which are known challenges in limb reconstruction.

Several technical considerations recur across the evidence. Technical planning is central to flap safety, and many papers emphasize that orthopedic and plastic surgical plans must be integrated before frame construction. The vascular pedicle and recipient vessels should be mapped with Doppler or CTA when possible. Pins and wires should not cross the anticipated pedicle or anastomosis. Although placement of pins through a free flap has been reported to be safe, the pin path must be planned carefully so that it does not pierce the pedicle.(15,16) Stoneburner et al. similarly state that pins through a free flap may be safe, but only with caution to avoid the pedicle. Li et al. suggested real-time flap monitoring and vascular exploration when flap crisis occurs(12). Repo et al. selected the distraction region to avoid direct stretching of the pedicle. Hohmann et al. and van Niekerk et al. elevated the flap from the side opposite the vascular pedicle during spacer removal.(6,7) This is an important practical point for later procedures such as cement spacer removal, docking-site freshening, and bone grafting.

Studies have also shown that defects managed in the acute setting were significantly more likely to require secondary surgical repair than chronic defects. This may reflect more controlled surgical management of chronic wounds before the study period, but variability in injury severity, patient comorbidities, surgeon expertise, and postoperative care limits the strength of this finding.(12) Careful collaboration between orthopedic and reconstructive surgeons is therefore needed to ensure safe distraction around the pedicle and microvascular anastomosis.

Timing and rate of bone transport are additional factors that may reduce the risk of flap loss. Few studies have described the effects of distraction on transferred free tissue and its anastomotic pedicle. Jupiter et al. (16) reported that free tissue and native tissue undergo equal magnitudes of stretch and lengthening without scar dehiscence after bone transport, despite differences in tensile strength and mechanical properties. In contrast, Horas et al. (17) noted a difference between the speed of bone transport and soft-tissue movement, which could potentially jeopardize the vascular pedicle; this risk increases as the amount of transport increases. Interestingly, the papers assessed in the systematic review performed distraction at 0.75–1 mm/day, suggesting broad agreement that this range provides optimal results.

Regarding timing of distraction, some authors performed corticotomy simultaneously, whereas others delayed distraction until after flap healing. Lowenberg et al. delayed transport for 10–14 days after corticotomy to permit initial flap healing and avoid immediate tension on the free-flap anastomosis.(3) Abulaiti et al. recommended an interval of approximately 3–4 weeks between successful flap survival and distraction, depending on clinical flap healing(18). However, immediate distraction osteogenesis with a recent free flap has not been shown to compromise the flap.(3)

Frame design also affects flap surgery. Ring fixators provide stability, but they may restrict the working space for microsurgery. LRS may be less bulky and may allow easier soft-tissue access in selected diaphyseal defects, as suggested by Elbeshry et al.(8) An open-ring construct may improve access for flap inset and re-exploration.(19) Yeo et al. highlighted that rings can also protect the flap from pressure and permit rescue access if a flap complication occurs, provided the operating window is adequate. Li et al. suggested that maintaining the mechanical axis during fixator application, minimizing angulation and rotation, limiting acute shortening to 4–6 cm, and monitoring distal circulation are key measures to avoid ischemia from vascular kinking.(11)

Secondary procedures at the docking site should be anticipated. Multiple studies reported docking-site nonunion, need for bone grafting, soft-tissue invagination, or refracture. Therefore, planned docking-site freshening, compression, autologous grafting, and readiness to safely re-elevate the flap should be incorporated into the treatment pathway.

Section 5: Risk of bias of included studies

Study	Tool used	Score	Level	Judgement
Hosny & Fadel 2003	JBI Case Series Checklist	6/10	Level IV	Moderate-high

Repo et al. 2016	JBI Case Series Checklist	7/10	Level IV	Moderate
Hohmann et al. 2017	JBI Case Series Checklist	8/10	Level IV	Moderate
van Niekerk et al. 2017	Newcastle–Ottawa Scale	7/9	Level III	Moderate
Elbeshry & Alabd 2019	JBI Case Series Checklist	7/10	Level IV	Moderate
Patel et al. 2021	JBI Case Series Checklist	8/10	Level IV	Moderate
Dheenadhayalan et al. 2022	JBI Case Series Checklist	8/10	Level III	Moderate
Necula et al. 2024	AMSTAR-2	Qualitative: critical concerns	Level V	High concern / low confidence
Li et al. 2021	JBI Case Series Checklist	8/10	Level IV	Moderate
Stoneburner et al., 2020	AMSTAR-2	approximately 5/16 domains adequately/partially met from reported methods	Level V	High concern / critically low confidence

Section 6: Level/strength of evidence

The included evidence is mainly composed of retrospective case series and retrospective cohort studies, with secondary-evidence systematic review. Overall, the risk of bias is moderate, with some studies having moderate-high concerns. The main limitations are small sample sizes, retrospective design, lack of randomized comparison groups, heterogeneous indications, mixed acute and chronic cases, and variable timing of flap coverage, fixator application and corticotomy. Also, bone-transport-under-flap outcomes are not always isolated. The systematic reviews are useful for secondary support but have high concerns because they are based mainly on non-randomized retrospective studies/case series. Despite these limitations, the direction of evidence is consistent. Most studies reported high union or limb salvage rates and acceptable flap survival. Flap-related complications were usually manageable.

Recommendation: Bone transport/distraction osteogenesis performed beneath or after flap coverage is recommended as a limb-salvage strategy for large traumatic bone defects with associated soft-tissue loss.However direct evidence is sparse in the literature and prospective comparative studies needs to be done.

References

1. Necula RD, Grigorescu S, Necula BR. Orthoplastic Reconstruction of Distal Tibia High-Energy Fractures Using a Circular External Fixator-A Systematic Review. J Clin Med. 2024 Sep 25;13(19):5700. doi:10.3390/jcm13195700 PubMed PMID: 39407767; PubMed Central PMCID: PMC11476398.

2. Tukiainen E, Asko-Seljavaara S. Use of the Ilizarov technique after a free microvascular muscle flap transplantation in massive trauma of the lower leg. Clin Orthop. 1993 Dec;(297):129–34. PubMed PMID: 8242920.

3. Lowenberg DW, Feibel RJ, Louie KW, Eshima I. Combined muscle flap and Ilizarov reconstruction for bone and soft tissue defects. Clin Orthop. 1996 Nov;(332):37–51. doi:10.1097/00003086-199611000-00007 PubMed PMID: 8913144.

4. Hosny G, Fadel M. Ilizarov external fixator for open fractures of the tibial shaft. Int Orthop. 2003 Oct 1;27(5):303–6. doi:10.1007/s00264-003-0476-3

5. Repo JP, Barner-Rasmussen I, Roine RP, Sintonen H, Tukiainen EJ. Treatment of compound tibia fracture with microvascular latissimus dorsi flap and the Ilizarov technique: A cross-sectional study of long-term outcomes. J Plast Reconstr Aesthetic Surg JPRAS. 2016 Apr;69(4):524–32. doi:10.1016/j.bjps.2015.12.011 PubMed PMID: 26843265.

6. Hohmann E, Birkholtz FF, Glatt V, Tetsworth K. The “Road to Union” protocol for the reconstruction of isolated complex high-energy tibial trauma [Internet]. 2017 Jun [cited 2026 Jun 15]. Available from: http://hdl.handle.net/2263/61535

7. Van Niekerk AH, Birkholtz FF, De Lange P, Tetsworth K, Hohmann E. Circular external fixation and cemented PMMA spacers for the treatment of complex tibial fractures and infected nonunions with segmental bone loss. J Orthop Surg. 2017 May 1;25(2):2309499017716242. doi:10.1177/2309499017716242

8. Elbeshry S, Alabd KhaledAA. Management of open tibial fractures type IIIB by segment transfer using limb reconstruction system fixator. Egypt Orthop J. 2019;54(2):110. doi:10.4103/eoj.eoj_21_19

9. Patel KH, Logan K, Krkovic M. Strategies and outcomes in severe open tibial shaft fractures at a major trauma center: A large retrospective case-series. World J Orthop. 2021 Jul 18;12(7):495–504. doi:10.5312/wjo.v12.i7.495 PubMed PMID: 34354937; PubMed Central PMCID: PMC8316841.

10. Dheenadhayalan J, Nagashree V, Devendra A, Jaganathan T, Rajasekaran S. Temporary spacer rod and plate technique: a novel intraoperative technical tip for minimizing the docking site malalignment during bone transport for bone loss in Gustilo IIIb open tibial fractures. Eur J Trauma Emerg Surg. 2023 Feb;49(1):523–30. doi:10.1007/s00068-022-02102-x

11. Li R, Zeng C, Yuan S, Chen Y, Zhao S, Ren GH. Free flap transplantation combined with Ilizarov bone transport for the treatment of severe composite tibial and soft tissue defects. J Int Med Res. 2021 May;49(5):3000605211017618. doi:10.1177/03000605211017618 PubMed PMID: 34044634; PubMed Central PMCID: PMC8168033.

12. Stoneburner J, Azadgoli B, Howell AC, Tucker D, Marecek G, Carey J. Review of soft tissue coverage options in distraction osteogenesis of the extremity. Plast Aesthetic Res. 2020 Mar 20;7(0):N/A-N/A. doi:10.20517/2347-9264.2019.028

13. Wu Y, Yin Q, Rui Y, Sun Z, Gu S. Ilizarov technique: Bone transport versus bone shortening-lengthening for tibial bone and soft-tissue defects. J Orthop Sci. 2018 Mar;23(2):341–5. doi:10.1016/j.jos.2017.12.002

14. Xu J, Zhong WR, Cheng L, Wang CY, Wen G, Han P, et al. The Combined Use of a Neurocutaneous Flap and the Ilizarov Technique for Reconstruction of Large Soft Tissue Defects and Bone Loss in the Tibia. Ann Plast Surg. 2017 May;78(5):543–8. doi:10.1097/SAP.0000000000000921 PubMed PMID: 28403000.

15. Fiebel RJ, Oliva A, Jackson RL, Louie K, Buncke HJ. Simultaneous free-tissue transfer and Ilizarov distraction osteosynthesis in lower extremity salvage: case report and review of the literature. J Trauma. 1994 Aug;37(2):322–7. PubMed PMID: 8064935.

16. Jupiter JB, Kour AK, Palumbo MD, Yaremchuk MJ. Limb reconstruction by free-tissue transfer combined with the Ilizarov method. Plast Reconstr Surg. 1991 Dec;88(6):943–51; discussion 952-954. doi:10.1097/00006534-199112000-00001 PubMed PMID: 1682964.

17. Horas K, Schnettler R, Maier G, Schneider G, Horas U. The role of soft-tissue traction forces in bone segment transport for callus distraction : A force measurement cadaver study on eight human femora using a novel intramedullary callus distraction system. Strateg Trauma Limb Reconstr. 2015 Apr;10(1):21–6. doi:10.1007/s11751-015-0220-8 PubMed PMID: 25820868; PubMed Central PMCID: PMC4395565.

18. Abula A, Yushan M, Ren P, Abulaiti A, Ma C, Yusufu A. Reconstruction of Soft Tissue Defects and Bone Loss in the Tibia by Flap Transfer and Bone Transport by Distraction Osteogenesis: A Case Series and Our Experience. Ann Plast Surg. 2020 May;84(5S Suppl 3):S202–7. doi:10.1097/SAP.0000000000002367 PubMed PMID: 32282415.

19. Yeo J, Sun JM, Moo IH, Yuan W, Boo HC, Yeo AKS. Ring-and-flap: a novel and accessible alternative to fix-and-flap in Gustilo IIIB-C open tibia fractures (an institutional experience). BMC Musculoskelet Disord. 2025 Nov 10;26(1):1033. doi:10.1186/s12891-025-09281-9