

4 When can we use strut grafts only

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Introduction

The first bone grafting was done in the early 1600s, when a bone from a dog was used to reconstruct a broken skull in a wounded soldier. Bone grafting procedures developed over the next 150 years in different parts of the world, and in 1821 the first graft of bone from one part of a person's body to another, the autograft, was performed in Germany. During the two World Wars, bone grafting continued to develop as bony wounds in many soldiers needed reconstruction.^{1,2} Over time, there has been a lot of development in the techniques of bone graft harvesting, as well as in the manufacture of different bone substitutes and biological materials to enhance bone formation. There are numerous different types and sources of bone graft.^{3,4} Depending on the requirement, bone graft may be cancellous only, corticocancellous, tricortical, cortical, or even vascularized. Common donor sites are the iliac crest (most frequently used), ribs, proximal tibia, the proximal 2/3rd of the fibula, distal end of the radius, distal end of the tibia, greater trochanter, and the olecranon process.^{5,6} On the basis of source, it can be an autograft, allograft, homograft, or heterograft. Autogenous grafts are safe and are still the standard globally. An autologous bone graft has the desirable qualities of good osteoinduction, osteoconduction, and osteogenesis with minimal adverse reactions.^{5,7} Strut bone grafts have added the advantage of structural support together with osteogenesis.⁸ Decision making on selection of the best donor site and type of bone graft (nonvascularized or vascularized) depends on multiple factors like the defect size, donor–host anatomical compatibility, type of

the graft and structural support needed at the defect site, duration of the procedure, donor-site morbidity, and the expertise needed to perform the procedure.

One of the disadvantages of autogenous bone graft is “donor-site pain.” To avoid this, use of allografts and bone grafts from other sources is common in developed parts of the world but are less in use in developing countries. Although cultural and religious issues may play a role, lack of facilities for refrigeration and sterilization is probably the primary cause for this. Nowadays, different types of bone substitutes are available in the market and can be chosen selectively for clinical use. Some of them are derived from biological products such as demineralized bone matrix, platelet-rich plasma, hydroxyapatite, and adjunction of growth factors (like bone morphogenetic protein). Others are synthetic such as calcium sulfate, tri-calcium phosphate ceramics, bioactive glasses, or polymer-based substitutes.⁴ Again, the cost of many of these products limits their use in developing countries. Thus, autogenous bone graft can be considered the gold standard, both biologically and financially, in low- and middle-income countries (LMICs).

Use of strut graft alone without instrumentation

A graft procedure can be considered successful when graft incorporation results in a biomechanically competent graft. Graft incorporation implies a viable graft with successful union of the graft and host, and good attachment to the soft-tissue bed providing long-term performance.⁹ In the context of spine surgery, a strut graft is used to reconstruct the anterior column of the spine

in conditions where the anterior column is shortened, after discectomy or corpectomy, in kyphosis, or following injury, infection, or neoplasm. The spine segment is then fixed with internal fixation devices, anteriorly and/or posteriorly. These additional implants support the fixation and maintain reduction and prevent graft subsidence or contact osteolysis. However, they can also increase the segmental stiffness. Rigid fixation, with static anterior plating, may cause stress shielding of the graft, reducing the mechanical load necessary for efficient graft healing.^{10–12} According to the Wolff law, a compressive force is necessary for healing of a bone. In an anterior reconstruction of the thoracic and lumbar spine, the strut graft should ideally bear about 70% of the load for healthy arthrodesis and, hence, the bone graft should work as an implant because the stress-shielding effect of an implant causes inactivity like a bed rest at the grafted site and chance of healing diminishes.¹³ Yin et al¹⁴ found greater stability at the grafted site when the size of the graft was increased by 140%, suggesting there is no need for added instrumentation with larger grafts.

When is this considered

Strut grafts alone without instrumentation can be used for support and fusion if the posterior ligamentous structures are maintained. In the cervical spine, a single-level or at most a double-level discectomy or single-level corpectomy can be supported and fused with strut grafts (tricortical graft from the iliac crest or from the fibula) without using support from other devices.¹⁵ Minami et al¹⁶ found good stability in kyphotic cervical spines, with inlay graft of nonvascularized or vascularized fibula placed in a gutter made in the vertebral bodies. Fractures limited to one segment and disk space can be treated by monosegmental fusion through bone strut graft.¹⁷ In fractures without deficiency in the anterior longitudinal ligament and annulus, “press-fit” impaction of an oversized anterior strut graft can be stable and provide good graft–vertebral body interface leading to healing without the need for supplemental implants.⁸ The use of stand-alone graft in deformity and fractures is not preferable in

the current scenario. There are higher chances of failure and need external immobilization. In cases of tubercular spondylitis (Pott’s spine) of thoracic spine needing thoracotomy, the ribs can be used as a strut graft after debridement to decompress the spinal cord. Bansal et al¹⁸ studied the operative treatment of tubercular spondylitis using fibular strut grafts, rib grafts, and cancellous bone grafts. They advised utilization of the mechanical strength of the fibular strut along with cancellous bone graft to support the affected segment, and to correct local kyphosis. They reported no further progression of deformity even without any instrumentation. Similarly, in the lumbar and lumbosacral region, fibular graft or a tricortical iliac crest graft can be used as a strut graft in different conditions needing discectomy or corpectomy.¹⁸ Transvertebral trans-sacral Dowel fibular strut grafting is a useful surgical adjunct in high-grade spondylolisthesis that is partially reduced.¹⁹

A free vascularized bone flap was first performed during the mid-1970s by Taylor mostly to reconstruct jaw bones; the first vascularized bone graft (VBG) harvested was the fibula followed by the iliac crest.²⁰ In 1980, Bradford²¹ reported that a vascularized rib graft is suitable for situations that require strong biomechanical support to reconstruct the anterior spinal column. VBGs are also useful in spinal malignancy that require radiation therapy. Several VBGs have been introduced for reconstruction and augmenting fusion of the spine. VBG has been successful in increasing the speed of acquisition as well as the ultimate stability of the fusion, by avoiding the process of creeping substitution.^{20,22,23} Vascularized bone grafting is indicated in cases with certain risks restricting the use of non-VBG (**Box 4.1**).

Box 4.1 Indications for vascularized bone grafting

- Failed fusion or pseudoarthrosis of the spine
- Large defects of >5 cm
- Gap associated with spinal infection (spondylodiscitis)
- Osteoporosis
- Severe kyphotic deformity
- Treatment plan including radiotherapy

Pitfalls

The graft cannot exert its biologic activity in isolation. It is dependent on the surrounding environment for cellular response and, in some cases, for blood supply. The mechanical environment of the graft site is also important. Bone and soft-tissue grafts are remodeled in response to the mechanical load. Excessive, inadequate, and inappropriate loads may be deleterious. Thus, the environment into which a graft is placed is an extremely influential factor in its ultimate success or failure.²⁴ On the other hand, mechanical function is dependent not only on the biology of the transplanted tissue but also on surgical technique, stability of fixation, postoperative rehabilitation, and general health of the patient. In cases with large post-debridement gap, spanning more than two disk spaces, needing long graft, there are higher chances of graft failure²⁵ and need instrumentation. Donor-site complications are well known in autologous bone grafting procedures. Injury to the neurovascular structures, infection, and donor-site pain are common complications.^{26–28} The structural issues at the donor site can be reduced by using materials like hydroxyapatite-bioactive glass ceramic composite to reconstruct the defect after graft harvest.²⁹ Herniation of abdominal viscera through the ilium at bone graft donor sites has been frequently reported.³⁰

Graft loosening, dislodgement, and graft fracture are undesired complications of strut bone grafting without instrumentation. Selection of the type of graft, retrieving appropriate size, meticulous technical details to ensure proper graft site preparation, and snugly fit graft are essential to minimize these complications.

A nonvascularized graft can potentially be a source of infection. Long-bone struts, particularly the fibula, may fracture at its center due to poor vascularity and resorption of the bone while two ends are healing. Usually, the window period for fracture is 6 to 8 months of graft. Smoking is a risk factor for poor incorporation of the graft. Creeping substitution of the graft may lead to nonunion or pseudoarthrosis (**Table 4.1**). These complications are found to be relatively high (17–35%) with long anterior strut grafting.^{31,32}

VBGs have better healing, superior mechanical support, and are more infection resistant.^{20,22,23} However, increased operative time and anesthesia-related morbidity, donor-site morbidity, and increased blood loss have precluded their widespread acceptance.

Rib grafts

Although used as an autologous graft to reconstruct the spine in early 1990s, ribs are not a frequently used source of autologous bone graft for spinal reconstructive surgeries. However, they remain a potential source where a long structural graft needs to be used as a strut. The ribcage can be a good donor site for either nonvascularized or vascularized cortical bone graft needed for any anterior pathologies.³³ Use of a vascularized rib graft in situations that require strong biomechanical support to reconstruct anterior spinal column has been suggested by many spine surgeons.^{34–36} Anatomically, the rib is a curved and flexible flat bone, and can provide a graft up to 30 cm in length. The shape and size of the graft can be tailored according to the requirement, by taking the graft

Table 4.1 Complications of autologous bone grafts

At donor site	At recipient site
Injury to the neurovascular structures	Graft loosening and dislodgement
Hematoma or seroma formation	Fracture of the graft
Donor-site pain	Graft subsidence
Visceral herniation through iliac defect	Nonunion; pseudoarthrosis
Fracture of the donor bone	Vascularized graft failure
Infection	Nidus for infection

from a specific site—a flat graft is taken from the posterior part and a curved graft is taken from the anterior part of the rib. Mechanically, a rib graft is weak when subjected to compressive forces. To overcome this, bundled or laminated grafts,^{37–40} or a folded vascular rib graft,⁴¹ have shown promising results in anterior spine arthrodesis. Rib grafting has a relatively low infection rate, and less donor-site pain. The rib strut graft is used in many conditions where the anterior column is shortened, eg, Pott's spine, pyogenic spondylodiscitis, trauma, adolescent idiopathic scoliosis, Scheuermann's kyphosis, and primary or secondary spinal tumors.^{22,23,39,42} The unique shape of the rib graft provides an excellent graft–host bone bed contact in occipitocervical fusion in children.⁴³ Mosheiff et al⁴⁴ treated two pediatric Pott's spine patients with acute thoracic kyphosis with vascularized rib graft without posterior instrumentation and both of them had excellent recovery. Nakamura et al⁴⁵ found solid bone union in all cases with vascularized rib graft folded into three to four pieces, which were used in different thoracic spine pathologies. Vascular pedicle rib graft is claimed to be a straightforward approach to reconstruct the anterior transthoracic fusion procedures.^{36,46}

Rib graft is contraindicated in patients with compromised lung function. It might be difficult to localize the rib in an obese individual.

Preparation and selection

Anesthesia and patient positioning

General anesthesia with double-lumen endotracheal tube is placed to deflate the near lung for single-lung ventilation during the procedure. The patient is placed in the prone position if a posterior procedure is planned. For an anterior procedure, the patient is placed in a lateral decubitus position with the graft site up. A bolster is placed, or the table is flexed at the mid-thoracic or thoracolumbar spine level to separate the ribs. The ipsilateral shoulder is gently pulled up and anteriorly to facilitate localization and dissection of the entire length of the rib. The donor-site area is prepared and draped.

Exposure

The rib, which corresponds to the collapsed vertebral level or one level superior, is selected for graft purposes. The sterno-manubrial joint that corresponds to the second rib can be a bony landmark for counting and localizing the targeted rib. For a thoracolumbar or lumbar spine anterior reconstruction, the 9/10th rib is suitable for harvest. Skin incision is given over the rib, and subcutaneous tissue is divided with electrocautery in line with the skin incision. Once the muscle fascia has been reached, the underlying rib is palpated and the muscle and fascia are divided with electrocautery directly over the chosen rib. For nonvascularized grafts, the periosteum is also divided and stripped together with the soft tissues. Dissection is easier and safer from the cephalad to caudad approach since the neurovascular structures are located at the distal edge of the rib. The periosteum on the outer surface is stripped with a periosteal elevator or a fine cub dissector. The periosteum on the pleural surface is completely stripped with a rib stripper all the way to the vertebral and sternal ends of the ribs. The rib is excised by dividing it at its costochondral and costovertebral junctions with a rib cutter (**Fig. 4.1**). In cases of tubercular infections, the rib head is disarticulated from its medial articulation with the vertebral body.

Vascularized rib graft

To harvest a vascularized rib graft, the periosteum of the rib is carefully preserved. The intercostal muscles are

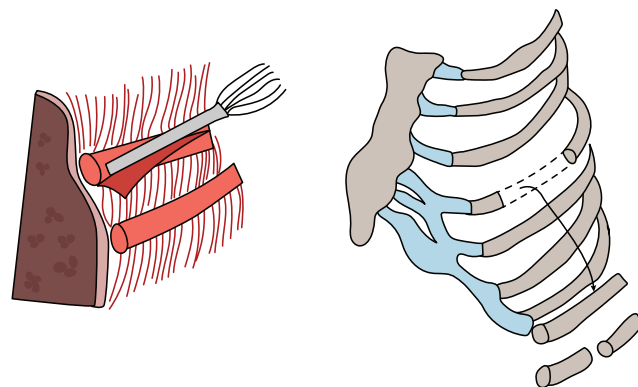


Fig. 4.1 Harvesting a nonvascularized rib graft.

divided sharply above and below the selected rib to protect the periosteum and vessels. Anteriorly, the vessels are ligated and divided along with the rib. Posteriorly, the periosteum is carefully incised all around the rib and rasped preserving the vascular bundle. The rib is elevated with its accompanying intercostal artery and vein as a pedicle (pedicle length of 3–5 cm). The intercostal nerve is separated from the vascularized rib. About 10 cm of a vascularized rib segment can be isolated, extending from near the costochondral junction to near the costal angle. Generally, the average length of the vascularized segment is 5–6 cm. The harvested graft is kept in a wet pad till implantation.

Technique for stabilization

The size of the graft should be slightly longer than the defect to obtain a press fit. For better strength against compressive loads, two or three segments of the rib can be bundled together with nonabsorbable suture or a thin cerclage wire. To accommodate an oversized graft, slots are made in healthy bone proximally and distally. Ends of the graft can be trimmed to snugly fit the graft between the proximal and distal vertebral bodies. Small pieces of ribs can be placed between the vertebral body and the anterior longitudinal ligament to span the void area.

The appropriately sized segment of the rib is mobilized around its vascular pedicle. Special care is taken not to twist, stretch, or fold the graft pedicle. Folding of the rib is done by sectioning the rib into two or three fragments of desired size without injuring the periosteum, to match the defect in the vertebral column. The rib is folded cautiously to prevent injury to the accompanying vessel. Folded vascularized rib graft provides immediate strength, and creeping substitution is avoided to enhance faster fusion.

If the grafted segment of the spine is fixed posteriorly, additional anterior instrumentation may not be necessary.

Iliac crest bone grafting for ASF

The iliac crest remains the gold standard donor site and is most frequently used for harvesting a bone graft; it can provide cancellous, corticocancellous, and tricortical bone grafts. The iliac crest strut graft is usually a tricortical graft and is used in bone defect of different sizes; the vascularized grafts can be longer than the nonvascular bone graft.^{45,47,48}

The anterior ilium has a concave anterosuperior surface. The anterior iliac crest is thickest (iliac tubercle) 2 to 3 cm posterior to the anterior superior iliac spine (ASIS). The lateral femoral cutaneous nerve typically courses medial to the ASIS; however, it can infrequently cross lateral to the ASIS and be at risk of injury. The posterior iliac crest thickness ranges from 14 to 17 mm. The superior cluneal nerve passes over the iliac crest 7–8 cm lateral to the posterior superior iliac spine (PSIS) and is at risk of injury with a lateral incision. The superior gluteal artery exits the pelvis from the greater sciatic notch and can be injured if bone harvesting approaches the sciatic notch. There are known donor-site complications of iliac crest bone graft (ICBG) that include “donor-site pain,” neurovascular injury, avulsion fractures of the ASIS, hematoma, infection, herniation of abdominal contents, gait disturbance, cosmetic deformity, violation of the sacroiliac joint, and urethral injury.^{47,49}

Preparation and selection

Anterior approach

Cancellous or corticocancellous or tricortical grafts can be obtained with this method.

Anesthesia and positioning

The patient is given general anesthesia for the anterior reconstructive surgery. A bolster is put under the buttock to make the iliac bone prominent. The part is scrubbed with soap water and then painted with iodine solution and draped.

Exposure

A skin incision is made, starting about 3 cm posterior to the ASIS, over the subcutaneous border of the iliac crest while stretching the skin toward the abdomen. (**Fig. 4.2**). Subcutaneous tissue and fascia are cut along with the skin incision with an electric cautery. Extent of the wound depends on the size of a tricortical graft from the anterior ilium. About 2–3 cm of the ASIS has to be preserved to avoid injury to the attachment of the sartorius muscle and the inguinal ligament, and to avoid an avulsion fracture. The lateral femoral cutaneous nerve should be protected if it has an anomalous course.



Fig. 4.2 The technique of stretching the skin toward the abdomen.

To harvest a tricortical graft, the wound is deepened down to the subcutaneous lateral margin of the iliac crest at the point of contact of the periosteum with attachments of the gluteal and trunk muscles. The soft tissue is cut along the margin of the crest; soft-tissue attachment in the lateral surface of the iliac crest is stripped subperiosteally, keeping the attachments intact in the superior surface (**Fig. 4.3**).

Depending on the size of the graft needed, soft-tissue attachment is marked and cut transversely (lateral to medial) with a sharp osteotome up to a depth of 1–2 mm. With a sharp osteotome, attachment of soft tissues in the upper surface of the iliac crest is lifted up together with a thin wafer of bone, then the iliacus muscle attachment in the medial surface of the iliac bone is cleaned down to a desired depth. The myo-osseous flap (wafer of bone, periosteum, abdominal muscles, and the iliacus muscle) is held with Ellis forceps so that it does not get retracted. Desired size tricortical graft is harvested after cutting both tables of the iliac bone on both sides with an osteotome or, preferably, a power saw. Then with slight prying motions with a broad osteotome or a chisel, graft is peeled. Excessive heat is avoided by irrigating with saline at room temperature. Hemostasis of the exposed bony surfaces is achieved using Gelfoam, bone wax, or both. After harvesting the graft, the myo-osseous flap is

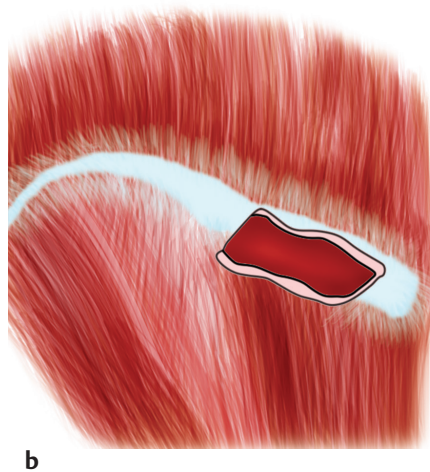
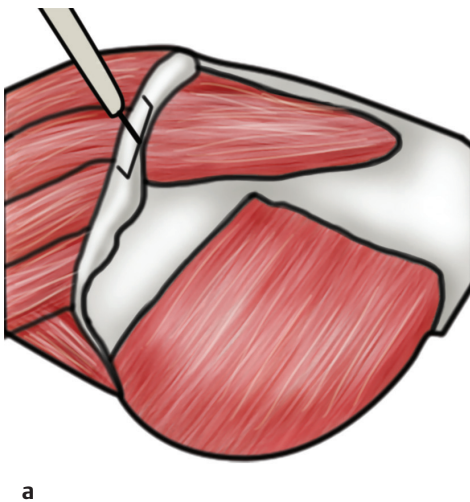


Fig. 4.3 (a) An incision is made on the outer margin of the iliac crest over the fascial attachment of muscles and periosteum. (b) The iliac crest after elevating the periosteum together with a wafer of bone.

accurately apposed and sutured with interrupted sutures maintaining the contour of the iliac crest (**Fig. 4.4**). The surgical wound is closed in layers and dressing is applied. Usually, placement of a drain is not necessary but if we put one overnight, it may prevent formation of a seroma. This technique preserves the iliac crest contour with intact osseo-periosteum-muscle attachment without autologous bone or external materials. The low-lying skin scar has better cosmesis and less irritation to waist garments.⁵⁰

The defect left after harvesting the strut graft is a more difficult problem. A large defect can leave a painful and unsightly waist that needs reconstruction of the iliac crest.

The vascularized iliac crest flap is superior to the nonvascularized graft.^{45,48} Vascularized muscle-pedicle bone flap taken from the anterior or posterior iliac crest is used to treat pseudoarthrosis in the lumbosacral area.^{20,48,51–53} The deep iliac circumflex artery (DICA),⁴⁸ superficial iliac circumflex artery (SICA), ascending branch of the lateral circumflex artery (ALCA), and iliolumbar artery⁵⁴ are generally used as nutrient vessels for the iliac bone flap. The commonly used vascular pedicle in ICBG is based on the DICA, which emerges from the external oblique muscle adjacent to the superior border of the iliac crest. The DICA may have different origins and courses.⁵² The external diameter of the artery is 1–5 mm

at its origin, and the distance to the ASIS is 6–27 (mean: 15.8 ± 5.6) mm.

Technique for stabilization

Stability of the graft is achieved by harvesting it from the thickest part of the ilium for wider graft-body contact, and an oversized graft for press fit. In cervical spine surgeries like anterior cervical discectomy and fusion (ACDF) or anterior cervical corpectomy and fusion (ACCF), the gap is measured using a caliper or a sterile disposable measuring tape, and a slightly oversized graft is retrieved. The adjacent vertebrae are distracted gently to accommodate the graft and press fit in the gap; after release, there will be compression at the grafted site. If necessary, with the use of a sharp osteotome or a high-speed burr, a proper-sized slot is made on the anterior part of the vertebral body with an inferior end plate of the cephalad vertebrae and superior end plate of the caudal vertebrae to snugly fit the graft. The graft should be placed in the antero-central part of the void disk space (1–2 mm posterior to the anterior vertebral margin) to maintain the lordosis and to prevent graft extrusion (**Figs. 4.5** and **4.6**). Depending on the condition, preserving the posterior longitudinal ligament in anterior cervical spine surgeries can provide stability.

In anterior reconstruction surgeries at the thoracic and lumbar spine, good size graft snugly fitted at the

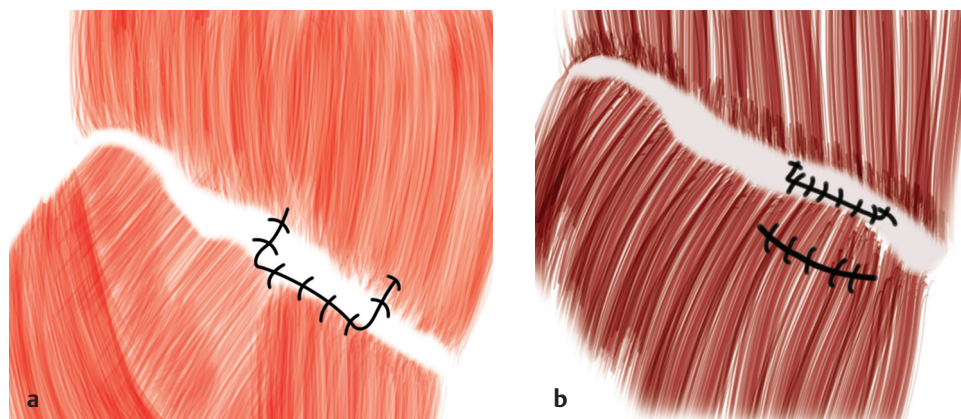


Fig. 4.4 (a) The periosteum with wafers of bone and muscles are opposed and sutured. (a) After suturing the incised skin. The external contour of the iliac crest is maintained and the skin suture is low lying.

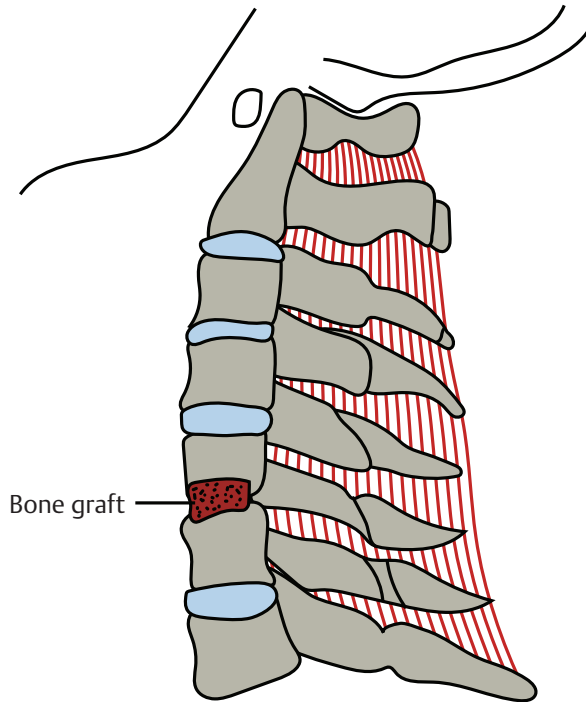


Fig. 4.5 Placement of the tricortical bone graft after diskectomy.

central part of the vertebral body can provide stability. Proper cleaning of the bed, removal of cartilaginous end plates of adjacent vertebrae, and good graft–bone contact in compression can enhance healing. Initial mechanical strength and faster healing is the key for stability of the spine segment.

Fibula and tibia grafts

Tibia and fibula

The tibia and fibula are long bones of the leg. The tibia is larger, stronger, and anterior (frontal) to the fibula and lies closer to the centerline. It bears about 80% of the body weight. Proximally the tibia articulates with the femur to form the knee joint, and distally the tibial plafond and medial malleolus form the ankle joint mortise. The anteromedial surface of the tibia is subcutaneous throughout its length. The wide flared metaphysis of the proximal tibia is one of the promising donor sites for cancellous bone graft and/or unicortical strut graft.

The fibula is a long bone in the lateral aspect of the leg that bears about 20% of the body weight. It has a proximal head, a slender shaft, and the distal end forms the lateral malleolus that completes the ankle mortise. The fibula articulates with the tibia through the proximal and distal tibiofibular joints (syndesmosis) and an interosseous membrane. Its three flat surfaces provide attachment to the muscles responsible for movement of the ankle-foot and the toes.

The common peroneal nerve courses obliquely from posterior to anterior over the fibular neck and divides into superficial, deep, and recurrent branches. The anterior tibial and peroneal vessels are in close proximity to the fibula, with the peroneal vessels just medial to the middle third of the shaft. The superficial peroneal nerve lies lateral to the fibula within the peroneus longus muscle, and the deep peroneal nerve and anterior tibial vessels are anteromedial to the fibula on the interosseous membrane.

The fibula is an excellent donor for a strut graft and can be considered a long-bone flap. This bone is long and straight, and has a good bone mass with a circumferential cortical profile with a higher modulus of elasticity. The central medullary canal can be packed with autologous cancellous bone to enhance fusion. Depending on the need, good lengths of graft can be harvested. Rangongo et al measured the ratio of the fibular graft surface area to that of the thoracic vertebral end plate and suggested that the footprint of a single fibular graft is good to reconstruct the upper thoracic vertebra and more than one fibular strut graft is needed to reconstruct the anterior column below that.⁵⁵

Provided the distal third (~7 cm from the syndesmosis) of the bone is not removed, fibula grafts can be harvested without much functional disability. The middle third of the fibula is the ideal area for harvesting a graft. The proximal and distal 10 cm should be avoided to reduce the risks of peroneal nerve damage and ankle instability, respectively.^{56,57}

As a strut, the fibula is commonly used in multilevel cervical corpectomies in disorders like trauma, infection,

disk diseases, multilevel cervical myelopathy, and kyphotic deformities. The fibular strut graft is ideal for reconstructing the anterior column in cervicothoracic junctional pathologies. A mechanically strong fibular graft is used to fill defects and support the vertebral column after debridement in Pott's spine, after resection of the vertebra in tumors, and correction of severe kyphotic deformities in the thoracolumbar spine.^{18,19,58,59}

Free vascularized fibular bone grafts (FVFGs) are very effective in managing bony defects caused by trauma, tumors, infection, or congenital anomalies. FVFGs have become the most commonly used free VBG in managing larger defects (<6 cm) where other conventional grafts have failed. Due to the fact that they have their own blood supply, FVFGs are effective even in cases where there is poor vascularity at the recipient site, such as in infection and following radiotherapy. Although it technically challenging and demanding, the FVFG can be an extremely useful salvage procedure.^{15,21,57}

Fibular graft harvesting is contraindicated if there is pre-existing ankle pain, neurological weakness, or vascular compromise in the limb. Possible complications of fibular graft harvesting are neurovascular injury, compartment syndrome, extensor hallucis longus weakness, and ankle instability.^{31,47}

The tibia provides dense cortical bone with ample length and mechanical strength, and is a useful alternative donor site for reconstructing bone defects.^{59,60} Autogenous tibial strut grafts have been successfully used in anterior spinal fusion for severe kyphosis and

kyphoscoliosis.^{61,62} Huang et al compared the morbidities of bone graft harvesting from the anterior iliac crest and proximal tibia and found that autogenous tibial strut grafts have minimal donor-site morbidity.⁴⁹ A tibial strut graft can be harvested from both medial and lateral approaches. Biomechanically the tibial strength after harvesting unicortical tibial grafts is a great concern.^{60,63}

Preparation and selection

Fibula grafting

Anesthesia and positioning

General anesthesia is usually given for spine surgery, and the bone grafting procedure is done in the same anesthesia. The patient can be placed prone, lateral, or supine. When the supine position is used, a bolster is put underneath the ipsilateral buttock and the knee/mid-calf for better visualization and access to the fibula. A thigh tourniquet is applied to make the surgical field bloodless. The limb is scrubbed with soap water and then painted with a povidone-iodine solution, and draped properly.

Exposure

A straight lateral skin incision is given over the posterolateral border of the fibula felt subcutaneously. Deeper dissection is carried out between the posterior and lateral compartments of the leg. The plane is dissected sharply until the bone can be palpated. The fibular surface is covered in muscle attachments that can be dissected using a subperiosteal technique. A curved bone

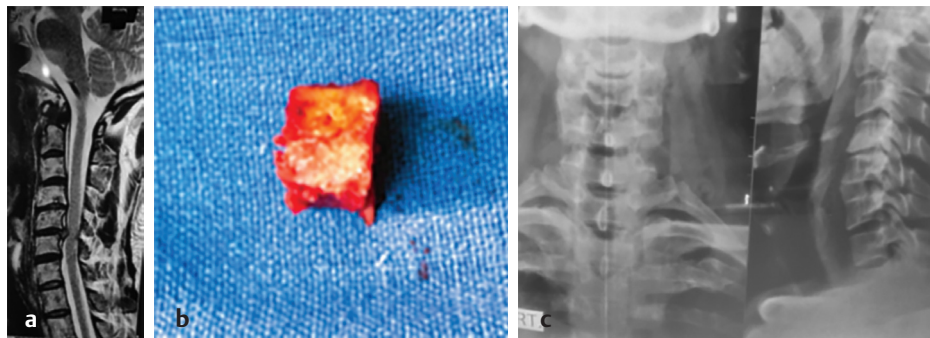


Fig. 4.6 A male patient presented with cervical radiculopathy. **(a)** Disk prolapse at the C5–6 level. **(b)** Tricortical bone graft retrieved from the iliac crest. **(c)** Anterior cervical discectomy and fusion (ACDF) was performed using a stand-alone tricortical bone graft at the C5–6 level.

elevator is used to free the interosseous border of the bone. The soft tissues are retracted to prevent injury, while a desired size of the bone graft is harvested with a Gigli saw or a power saw. Meticulous hemostasis is then achieved. The deep fascia is not closed in order to avoid compartment syndrome, and the wound is closed in layers after placing a drain (**Fig. 4.7**).

For a vascularized graft, a preoperative vascular study of the peroneal vessels should be performed by angiography or duplex ultrasonography. The peroneal vascular pedicle is dissected proximally to its bifurcation from the tibial vessels. The main nutrient artery enters the fibula in the middle third of the bone; therefore, the FVFG must include this section. The vascular pedicle consists of one peroneal artery (1.5–2.5 mm in diameter) and two vena comitantes (2–3 mm in diameter). Good blood flow to the fibula is confirmed after deflating the tourniquet. The peroneal artery and the peroneal vein are clipped and divided, leaving a vascular pedicle on the fibula as long as possible (usually 2–5 cm).

Tibia graft

The patient is positioned supine with the knee flexed between 30 and 45°. The bony landmarks are identified

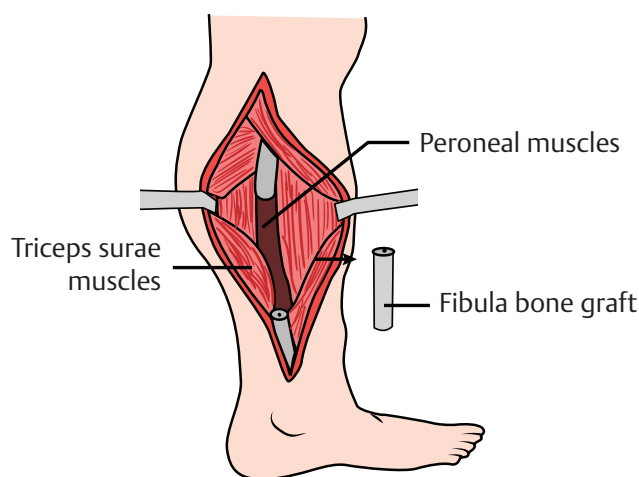


Fig. 4.7 Approach to harvest fibular strut graft from the mid-shaft of the fibula. Tibial bone graft showing the target point over Gerdy's tubercle for the lateral approach and the midpoint for the medial approach to harvest tibial strut graft.

and marked with a skin pen. A thigh tourniquet is used to make the operation field bloodless.

Medial approach

The surface landmarks, namely, the patella, medial border of the patellar tendon, tibial tuberosity, medial tibial condyle, and medial tibiofemoral space, are marked. An oblique skin incision is made 1.5 cm medial and cephalad to the tibial tuberosity. According to the desired length of the graft, the skin incision can be extended proximally or distally onto the shaft of the tibia.

Lateral approach

The surface bone landmarks, namely, the patella, lateral border of the patellar tendon, tibial tuberosity, Gerdy's tubercle, fibular head, lateral condyle of the tibia, and lateral tibiofemoral space, are marked. An oblique skin incision is made centered on Gerdy's tubercle (midpoint between the tibial tuberosity and the fibular head). As per need, the incision can be extended toward the tibial tuberosity and/or the shaft (**Fig. 4.7**).

After either incision, the incision is deepened down to the fascia and the periosteum. A subperiosteal dissection is made to expose the desired area of the bone. A corticocancellous bone piece of the desired size is harvested with a power saw and preserved in a wet gauze. The periosteum is closed with interrupted absorbable sutures and the wound is closed over a suction drain placed outside the periosteum. The limb can be protected in a long leg cast if weakening of the tibia is a concern.

In children

Under tourniquet, a longitudinal incision is made on the shin starting just distal to the tibial tuberosity and ending at a point just proximal to the distal tibial physis. The medial cortex is exposed subperiosteally and a long rectangular strut of cortical bone is harvested with a power saw. The medullary contents are then scooped out and also preserved for grafting. The periosteal sleeve is closed meticulously with interrupted absorbable sutures. The wound is closed over a suction drain placed outside the periosteum, and a long leg cast is applied.⁶⁴

Technique for stabilization

A fibular graft is a strong cortical bone segment. Proper preparation of the host site and removal of cartilaginous end plates and necrotic tissue play an important role in stability of the graft. Use of a slightly oversized graft, applying distraction at the spinal segment while placing the graft, and making slots in the host vertebrae are some of the techniques used to provide press fit of the graft.⁶⁵ Placement of the strut graft at the center or slightly anterior to the center of the vertebrae can maintain the height of the anterior column (correct the kyphosis) and can have a snug fit with the adjacent vertebral bodies (**Fig. 4.8**). Straight alignment of the strut graft has lower incidence of graft subsidence after anterior cervical corpectomy and better outcome compared to oblique alignment of the strut graft.⁶⁶ The FVFG provides better stability because of its initial strength, graft hypertrophy, and faster graft incorporation by avoidance of creeping substitution.

Others

The iliac crest, fibula, proximal tibia, and ribs are good sources for both nonvascularized and vascularized strut grafts to reconstruct the anterior spinal column and are established surgical procedures. There are other relatively new sources of bone graft for strut effect in spine

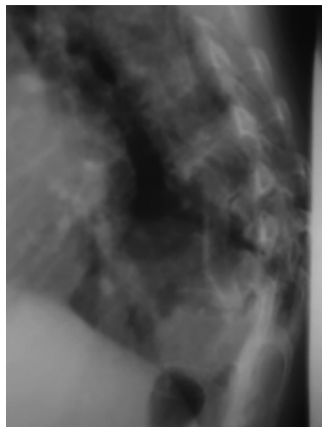


Fig. 4.8 The fibula as a strut to fill the gap after debridement of Pott's spine at the thoracolumbar spine.

surgery. Other sources of strut graft, which are locally available and easy to harvest, were explored.

Clavicle graft

The medial end of the clavicle is wider and can be a good source of corticocancellous graft, which can be used to reconstruct the anterior column of the cervicothoracic or upper thoracic spine. Sundaresan et al⁶⁷ resected the medial portion of the clavicle and the manubrium sterni to expose the upper two thoracic vertebrae and used the resected portion of the clavicle as a strut for anterior fusion. On the basis of a cadaveric study to assess the anatomical and technical feasibility of rotating a clavicular segment on a sternocleidomastoid muscle (SCM) pedicle into the ventral cervical spine, a patient was operated and the first clinical case had an encouraging result.⁶⁸

Scapula graft

Vascularized scapula grafts (S-VBGs), pedicled on the rhomboid minor, provide both structural support and a source of vascularized autograft to a cervicothoracic arthrodesis, which is better than the free flap bone graft.⁶⁹ This novel surgical technique, although it has been used in only a single case, has the advantages of vascularized structural autograft without the increased operative time and morbidity. Similar to successful use of the pedicled lateral S-VBG in humeral reconstruction, and preliminary result of the medial S-VBG, it has the potential to supplement complex cervicothoracic arthrodesis.

Transverse process and spinous process grafts

Liang et al⁷⁰ used the transverse process (TP) as a strut graft to treat single-segment thoracic tuberculosis and suggested that the TP as a strut could be a new bone graft method. In a retrospective cohort study comparing the clinical efficacy of three types of autologous strut grafts (lamina with the spinous process [LSP], TP, and iliac graft [IG]) to treat thoracic single-segment spinal tuberculosis, Tang et al⁷¹ concluded that the LSP and TP are reliable, safe, and effective for single-segment stability reconstruction for surgical management of thoracic

tuberculosis (TB). The autogenous spinous process bone graft was used to reconstruct the anterior column for single-segment lumbar pyogenic spondylitis.⁷² Considering the proximity of the donor site and tricortical property of the transverse and the spinous processes of the lumbar spine, they can be used as a strut in posterior lumbar interbody fusion (PLIF) or transforaminal lumbar interbody fusion (TLIF) surgeries.

Occipital bone graft

The occipitocervical junction and the atlantoaxial region are critical areas with high mobility, and are prone to developing instability due to injury, infection, rheumatoid arthritis, or in Down's syndrome. Hypermobility in this area predisposes to nonunion and hardware failure with conventional stabilization techniques. This novel occipital VBG (O-VBG), pedicled on the semispinalis capitis muscle, is an easily accessible and effective technique without prolong operative time, and has least morbidity. The O-VBG augments fusion with stability.^{69,73}

Conclusion

Bone grafting is an integral part of orthopedic surgery to reconstruct the skeleton and enhance bone healing. Spinal disorders like trauma, infections, tumors, and congenital disorders leading to kyphotic deformity or vertebral body and disk deficiency after surgical debridement need reconstruction of the anterior column using biological and mechanical support. To avoid donor-site morbidities, an allograft is used; however, the

autologous bone graft remains the gold standard and meets all the properties necessary for bone healing, and strut grafts have additional mechanical support. In most of the cases, a free strut graft is good enough for bone healing; however, a VBG has the additional advantage of a "living bone segment as a graft" and is used in special conditions. Local mobilization of a pedicled vascular graft has the advantage of reduction of time for harvesting a vascularized graft and anastomosis with recipient vessels in free VBGs. The iliac crest, fibula, and ribs are good sources of strut grafts for spine surgery. The iliac crest graft is the gold standard for corticocancellous and tricortical bone graft. Fibular strut grafts are used where more mechanical support is needed. The tibia can be an alternative donor site for a strut graft. The rib bundle is a good source of strut grafts to reconstruct the thoracic spine with relatively low donor-site morbidity (**Table 4.2**).

The search for a locally available strut bone grafts from parts of the vertebra and nearby structures is going on with encouraging preliminary results. In future, a successful bone healing can be achieved by new bone graft techniques with minimum donor-site morbidity. Proper selection of the graft, proper preparation of the recipient bed, and meticulous surgical techniques are key to successful bone healing after bone grafting. Stability of the grafted segments of the vertebral column is a great concern. In conditions where the posterior ligament complex and two facets are intact, a snugly fitted strut graft can provide good stability without added instrumentation.

Table 4.2 Comparison between different types of strut grafts (iliac crest bone graft, rib, fibula, tibia)

Site	Rib	Iliac crest	Fibula	Tibia
Bone type	Corticocancellous	Corticocancellous	Cortical	Corticocancellous
Strength to compression force	Weak	Strong	Very strong	Strong
Optimal length of harvest	Up to 5–6 cm	Up to 4 cm	>6 cm	Up to 5–6 cm
Donor-site complication	Less	Donor-site pain	Ankle weakness	Fracture of the tibia
Recipient site complication	Dislodgement Graft fracture	Dislodgement	Fracture	Fracture
Source for vascularized graft	Common	Common	Very common	Not common

In the cases with unstable spinal segments, posterior fixation is necessary for stability; however, anterior instrumentation can be avoided with good selection and fitting of the strut graft (**Fig. 4.9**).

Socioeconomic issues of using allografts and cost of the commercially available implants and bone-forming

materials are major constraints for their use in LMICs; however, the art of retrieving autologous bone grafts with improvement in technique to reduce complications has helped achieve satisfactory outcomes in spine surgeries.

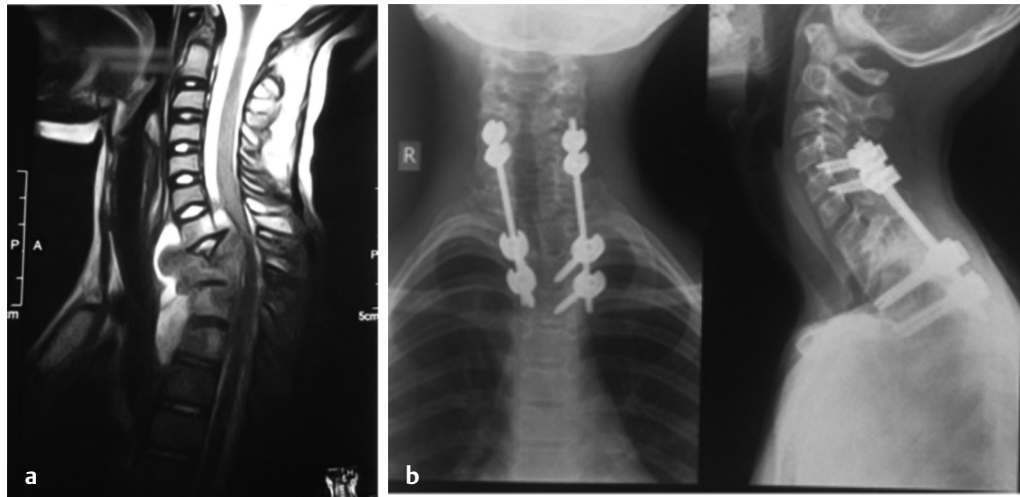


Fig. 4.9 (a) Pott's spine at the cervicothoracic junction. (b) Anterior debridement and fibular strut graft with posterior instrumentation 10 years after the surgery.

Key points

- Bone grafting is an integral part of orthopedic surgery; autologous graft remains the gold standard.
- Besides the biological properties of the graft, mechanical strength of the graft is used as a strut to support the vertebral column.
- Although there are many sources of bone graft, the tricortical iliac crest, tubular fibula, and bundled rib grafts are mostly used as a stand-alone strut graft.
- Retrieving a proper size and type of graft and meticulous preparation of the bone bed are key to a successful spine surgery.
- Locally available strut bone grafts from parts of the vertebra and nearby structures have provided encouraging results and these can be a better alternative with less donor-site morbidity.

Acknowledgments

We would like to thank Dr Akinchan Kafle for the sketch of the ICBG technique and Mr Subash Chandra Sharma, assistant professor, Department of Psychiatry, Kathmandu Medical College, for his help in referencing and editing. We would also like to thank Prof AR Bajracharya for the photographs in the chapter.

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