Percutaneous Osseointegration Prosthesis

26

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26.1 Introduction

Above knee amputation has not been the standard of care for lower extremity bone and soft tissue sarcoma since it was shown wide surgical margins have the same oncologic outcomes as radical margins, leading to limb salvage in most cases [1]. While patients heavily favor saving the limb whenever possible, physicians also observe the poor function and difficulty with socket prostheses most patients experience following above knee amputation [2]. However, with the advent of bone anchored osseointegration prostheses, there is now another amputation reconstruction option that should be considered preoperatively. Despite skepticism regarding infection risk, osseointegration amputation reconstruction has demonstrated excellent results and patient satisfaction versus sockets in multiple studies [3, 4] with intermediate follow-up, and recently a study with 15-year follow-up demonstrated implant retention in 72% of cases [5]. These results have led a growing number of surgeons to add osseointegration to their armamentarium and surgical decision making, especially when a planned tumor resection will be technically difficult with safe margins or will leave the resultant limb with limited motor function or severe dysesthesia. In selected cases, the pendulum may swing away from an amputation being viewed as "giving up" and toward providing the patient with the best outcome physically, functionally, and emotionally.

26.2 Brief Clinical History

(a) A 50-year-old man sustained multiple ipsilateral lower extremity open fractures resulting in ~40 surgeries complicated by persistent infection leading to a transfemoral amputation 1 year prior to presentation. He noted excessive soft tissue at the amputation stump with dependent edema and experienced frequent electrical nerve pain and blistering of the skin with socket use. There was no obvious infection since the amputation.

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26.3 Preoperative Images and Radiographs

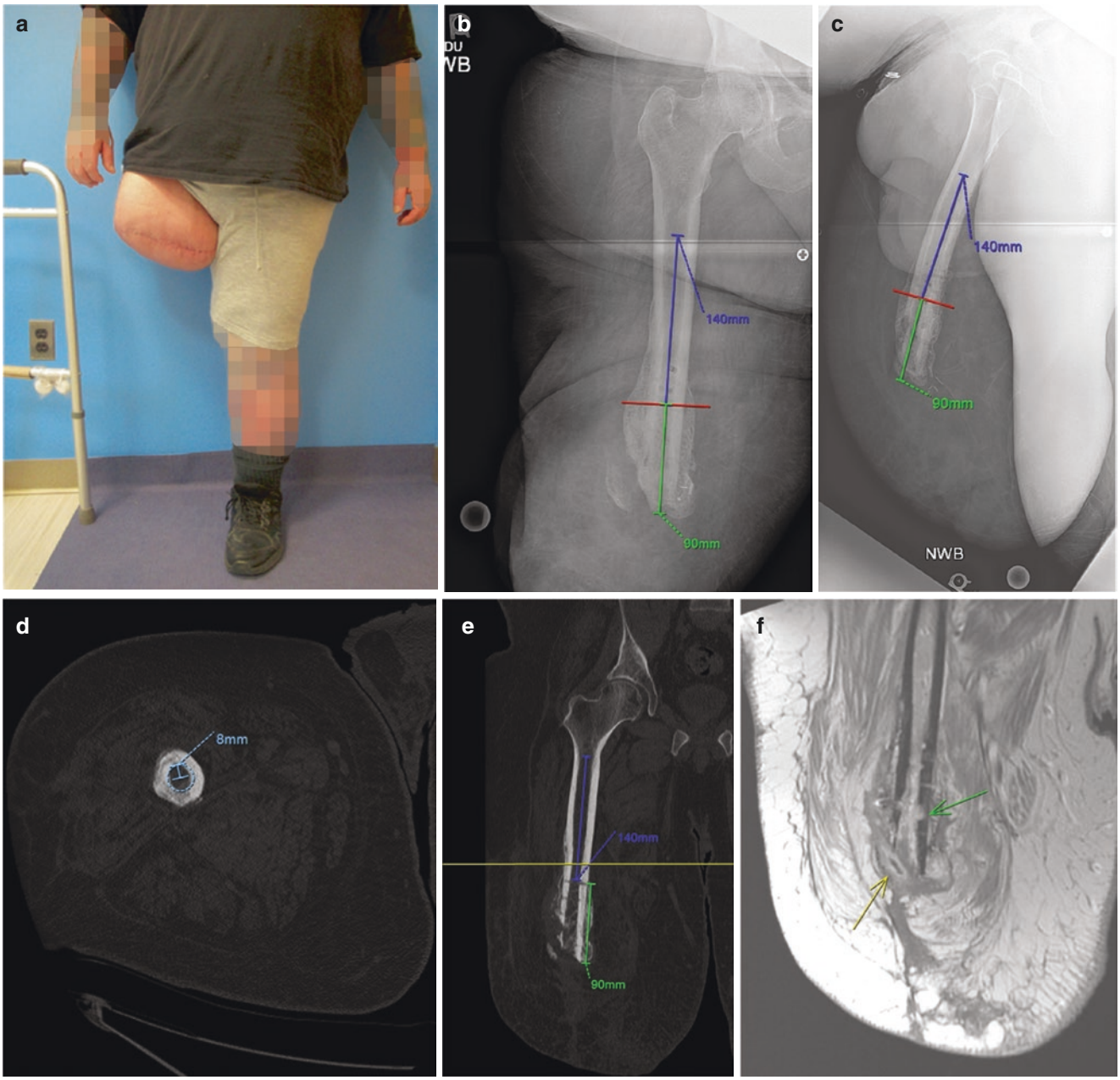

Fig. 26.1 (**a**) Standing preoperative photograph showing a wide thigh with excessive soft tissue. (**b**) AP radiograph with planned resection margin and implant length. (**c**) Lateral radiograph with planned resection margin and implant length. (**d**) Preoperative CT with planned implant diameter. (**e**) Preoperative CT with planned resection and implant length, axial slice in (**d**) demonstrated by yellow line. (**f**) Sagittal T1 MRI demonstrating bone erosion (green arrow) and small fluid collection (yellow arrow) consistent with osteomyelitis of the distal residual femur

26.4 Preoperative Problem List

(a) Transfemoral amputation.
(b) Mottled residual distal femur with MRI evidence of osteomyelitis.
(c) Excess soft tissue with multiple residual scars and clefts.
(d) Blistering of skin with socket use.
(e) Nerve pain with socket use.
(f) Very limited mobility.
(g) History of depression/psychiatric admission for hopelessness.

26.5 Treatment Strategy

(a) The distal femur had evidence of osteomyelitis on MR imaging consistent with history of severe persistent infection. The mottled infected bone needs to be resected to normal appearing diaphysis.
(b) An antibiotic cement spacer will be placed in the femoral canal in conjunction with culture specific antibiotics to treat the residual infection.
(c) The soft tissue reconstruction/thigh lift will be performed during the initial surgery to remove excess tissue and shape the residual stump in preparation for a staged, percutaneous osseointegration implant.
(d) Excision of any sciatic neuroma and targeted muscle reinnervation will be used to treat the residual nerve symptoms (performed by a plastic surgery colleague).

26.6 Basic Principles

(a) Osseointegration employs a prosthesis with a surface coating that facilitates bone ongrowth or ingrowth to stabilize the bone prosthesis interface, similar to femoral stems in hip replacement. Once integrated, the interface is resistant to deep infection and highly durable, capable of sustaining the loads of normal ambulation. While having a longer interface with the diaphysis is desirable (14 cm is a good target), successful osseointegration implants often function with much less (5–6 cm). Cementing the prosthesis in the bone prevents osseointegration and should not be performed [6].
(b) To obtain integration the bone should be sterile, so any known or suspected residual infection should be treated with an antibiotic spacer prior to definitive implantation. Thorough debridement and use of absorbable antibiotic ceramics may make single stage implantation possible in the future but would not be considered standard of care at this time.
(c) After eradication of infection two options exist—implant the stem of the prosthesis and allow bone ingrowth for 6–12 weeks within a closed soft tissue envelope (considered the "traditional" approach) or implant the stem and create the stoma in a single surgery and permit immediate gradual weight bearing to facilitate osseointegration. Both methods have been successful [3, 7].
(d) The soft tissue reconstruction requires a paradigm shift away from normal "socket" management where the goal is to use muscle to act as cushion for the bone end. In osseointegration, the goal is to minimize and wrap muscle around the bone implant interface, minimize fat, and tighten and stabilize skin at the stoma. A purse string myoplasty is performed at the bone end, and the subcutaneous fat is thinned to allow the skin to form a seal around the prosthesis. Excess soft tissue leads to drainage and increased shear on the skin, both of which are considered contributors to superficial infections.
(e) A calibrated preoperative XR will determine how much bone resection is necessary to achieve a circumferential ring of diaphysis to abut the prosthesis and the available length for the intramedullary portion of the implant (Fig. 26.1b and c).
(f) A preoperative CT is mandatory for custom implant planning. The diameter of the implant is determined via the endosteal bone diameter. The implant must achieve press fit immediately, thus the ingrowth portion of the implant may overlap the inner cortical surface when planning (Fig. 26.1d and e).
(g) A preoperative MRI (if not already obtained for oncologic reasons) is utilized if there is any suspicion for active or residual infection (Fig. 26.1f). A positive result warrants staged reconstruction after antibiotic spacer placement. MRI can also evaluate the available soft tissue if there is concern for coverage of the prosthesis.

26.7 Images During Treatment

See Fig. 26.2.

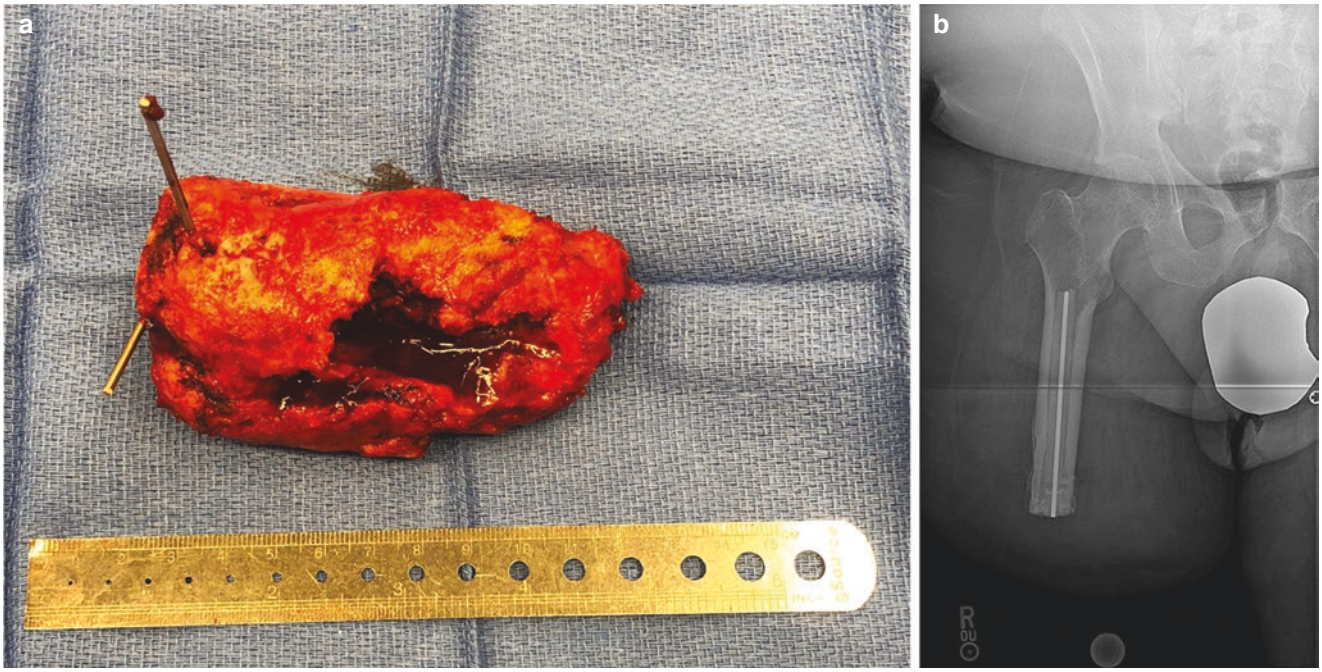

Fig. 26.2 (**a**) Resected distal residual femur. The wires were used to make a transverse cut in the diaphysis. (**b**) AP radiograph of femur with intramedullary cement spacer loaded with antibiotics (40 g of poly (methyl methacrylate) bone cement with 2 g of vancomycin and 3.4 g of tobramycin)

26.8 Technical Pearls

(a) Much like intramedullary nailing, a well-placed guidewire is the key to the initial portion of the operation. The wire is placed centrally in the bone and advanced past the expected endpoint of the prosthesis. Sequential reaming is then performed centrally over the wire. Eccentric removal of the cortex places the bone at risk for fracture.

(b) In the diaphyseal femur, most implants will have a bow to match the anterior bow of the femur. The broaches used for final preparation of the canal should be similarly bowed (Fig. 26.3).

(c) When advancing the implant into the bone, light to moderate mallet strikes should be sufficient if the canal is properly prepared. Resistance should be evaluated with fluoroscopy to prevent fracture. The press fit of the implant and the natural bow of the femur provide initial rotational stability.

(d) A purse string suture of deep soft tissue is used to bring the adjacent muscle to the bone implant interface.

(e) The superficial stoma for the implant is created in a one-stage procedure by advancing a soft tissue flap over the prosthesis and cutting a small hole in the skin wide enough to permit the prosthesis.

26.9 Outcome Images and Radiographs

See Figs. 26.4, 26.5.

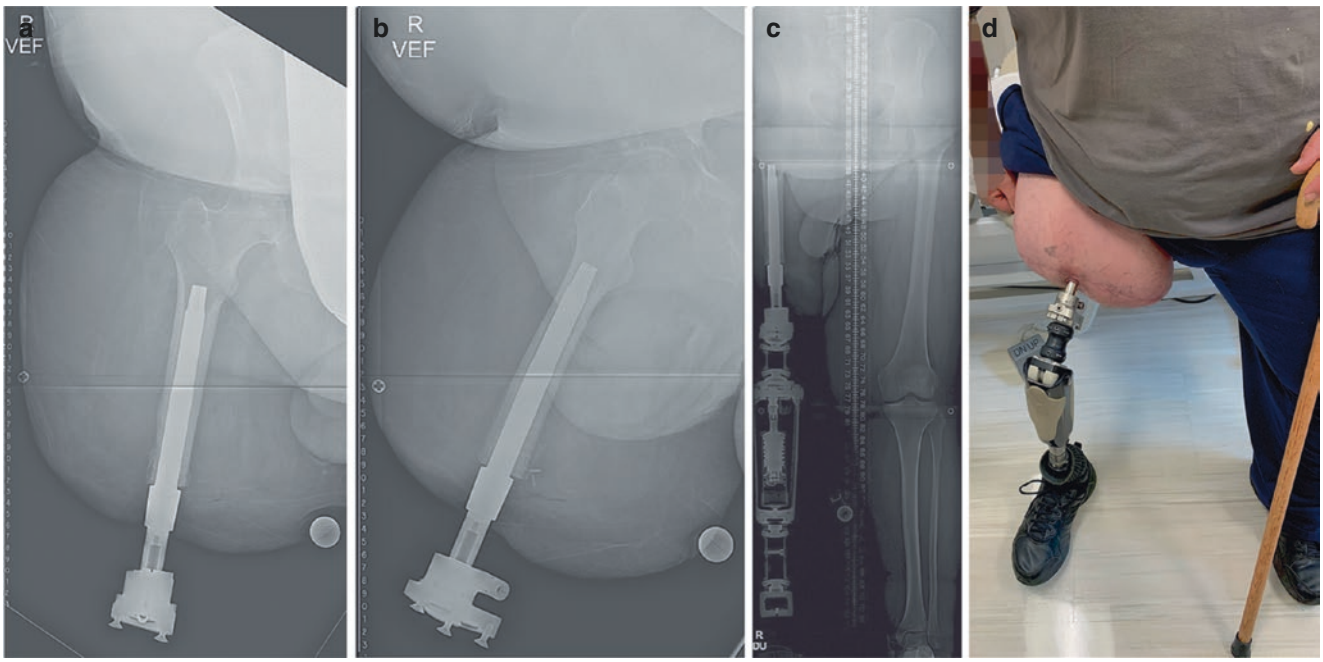

Fig. 26.3 (**a**) Initial postoperative AP radiograph with external loading apparatus. (**b**) Initial postoperative lateral radiograph. (**c**) Standing radiograph with leg attached. Note mechanical alignment of limb. The 1 cm leg length discrepancy can be adjusted through the prosthesis. (**d**) Photograph of patient with the leg attached

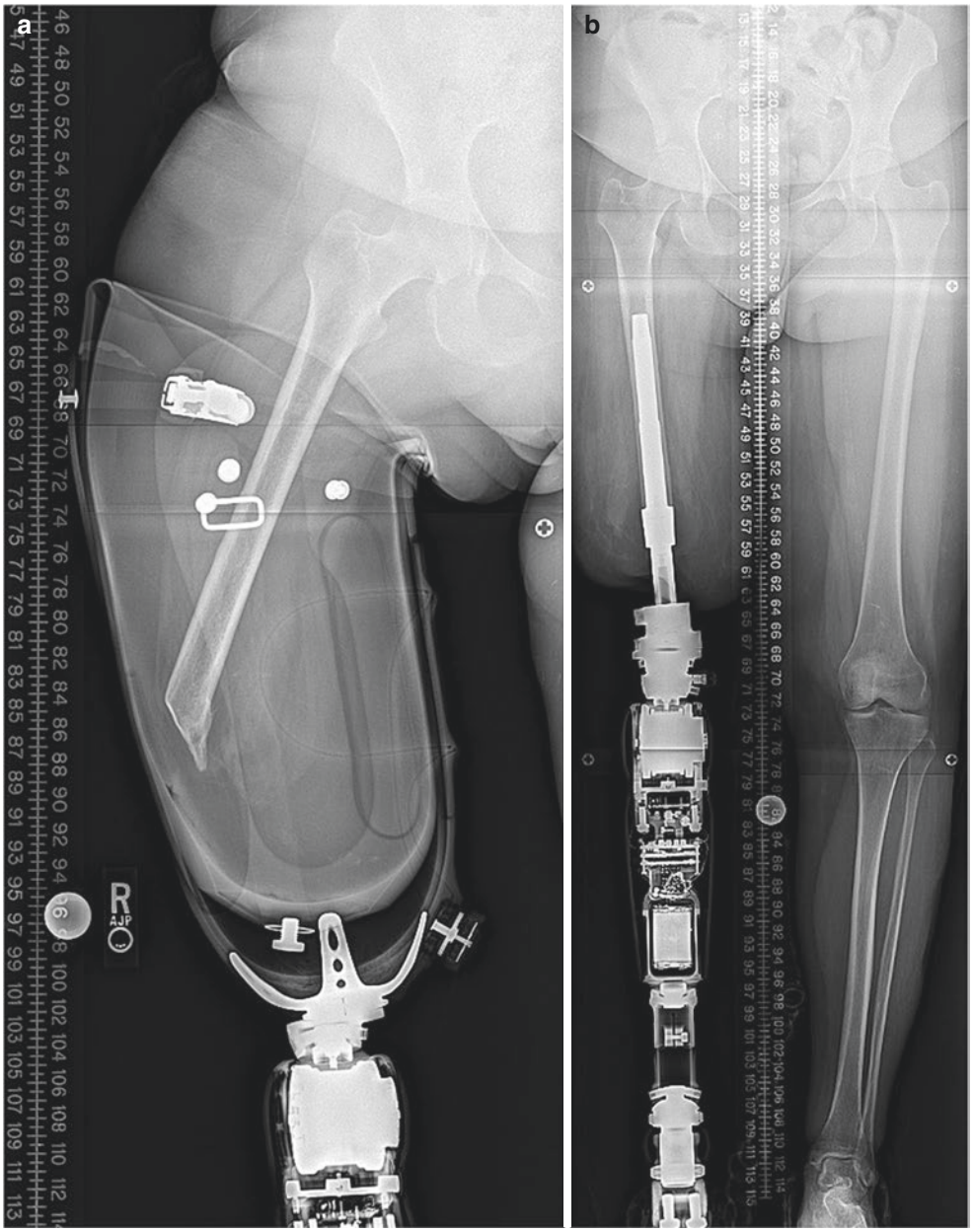

Fig. 26.4 (**a**) Preoperative AP radiograph of different patient standing in socket prosthesis Note poor position of femur for load transfer during ambulation. (**b**) AP standing radiograph of same patient after osseointegration prosthesis

Fig. 26.5 (**a**) Ideal soft tissue reconstruction and stoma appearance following osseointegration prosthesis implantation. (**b**) Close-up view of a healthy stoma

26.10 Avoiding and Managing Problems

(a) Given the relative youth of this procedure and the reliance on custom implants, extensive preoperative planning is essential to ensure success in the operating room. Unlike an allograft bone that can be contoured to the desired shape, the metal implant must fit the bone with press fit for osseointegration to be successful. Eventually, the procedure may proceed like a total hip arthroplasty with sequential sizes available, but for now proper sizing using the CT is mandatory.

(b) There is no agreed upon method for loading the prosthesis in the postoperative period, so the surgeon should use their judgment based on the quality and appearance of bone in the operating room. Stout bone with a long implant can be gradually loaded immediately with plan to attach a leg at 6 weeks, while thinner, brittle bone, or a shorter implant may benefit from an initial period of non–weight bearing or slower gradual loading with plan to attach a leg at 10–12 weeks. Our typical loading protocols use a rubber shoe on the abutment, initial load of 20 lbs. for 10–15 min, 4–6 times per day, and gradual increase of 5 pounds per day or every other day.

(c) An enthusiastic prosthetist is invaluable as part of the team treating a patient with an osseointegration implant. The prosthesis may require custom or modified components at the interface with the implant.

(d) Superficial infection has been a commonly reported complication of the procedure in the short and long term, but prompt administration of antibiotics prevents the majority of infections from progressing to a true periprosthetic infection requiring explantation. We believe the seal formed by bone ingrowth and fibrous tissue at the bone implant interface protects against deep infection.

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