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SURGICAL TECHNIQUE

Surgical Technique

Methods for Removing a Compress® Compliant Prestress Implant

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Abstract

Background The Compress® device uses a unique design using compressive forces to achieve bone ingrowth on the prosthesis. Because of its design, removal of this device may require special techniques to preserve host bone.

Description of Techniques Techniques needed include removal of a small amount of bone to relieve compressive forces, use of a pin extractor and/or Kirschner wires for removal of transfixation pins, and creation of a cortical window in the diaphysis to gain access to bone preventing removal of the anchor plug.

Methods We retrospectively reviewed the records of 63 patients receiving a Compress® device from 1996 to 2011 and identified 11 patients who underwent subsequent prosthesis removal. The minimum followup was 1 month (average, 20 months; range, 1–80 months). The most common reason for removal was infection (eight patients) and the most common underlying diagnosis was osteosarcoma (five patients). Three patients underwent above-knee amputation, whereas the others (eight patients) had further limb salvage procedures at the time of prosthesis removal.

Results Five patients had additional unplanned surgeries after explantation. Irrigation and débridement of the surgical wound was the most common unplanned procedure followed by latissimus free flap and hip prosthesis dislocation. At the time of followup, all patients were ambulating on either salvaged extremities or prostheses.

Conclusion Although removal of the Compress® device presents unique challenges, we describe techniques to address those challenges.

Introduction

One of the greatest challenges for surgeons resecting tumors in the extremities is the ability to provide long-term functional restoration of the involved limb while achieving local control and potentially preventing metastatic disease. Historically, the most predictable method of treating patients with extremity sarcomas was with amputation [18]. With time, musculoskeletal oncologists began to perform limb salvage surgeries using allograft [5, 22] or arthroplasty techniques [6, 15, 20, 21].

The endoprostheses used to perform limb salvage surgery use different types of fixation. Traditional prostheses have long, stiff, stemmed components, which may be either cemented or press-fit into host bone. This type of fixation, however, has the possibility of leading to stress shielding or osteolysis of the native bone, which can contribute to aseptic loosening and subsequent failure of the reconstruction. Failure rates in these constructs can range from 12% to 45% [1, 7, 10–12].

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
This work was performed at Stanford University Hospital and Clinics, Stanford, CA, USA.

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The Compress® Compliant Pre-Stress device (Biomet Inc, Warsaw, IN, USA), although also an intramedullary device, uses a different design to achieve bone ingrowth fixation and is intended to minimize stress shielding and osteolysis. It uses stored energy from Belleville washers to provide compliant compression through a short traction bow device (Fig. 1), which serves to promote bone ingrowth at the bone-prosthetic interface and as induce new bone formation at the intervening cortex (Fig. 2). Forces exerted on the involved extremity are transmitted directly from the implant to the host bone, thus eliminating stress shielding, and as osseointegration occurs, the medullary canal is sealed and protected from wear particles, which may induce osteolysis [1, 2, 7, 11].

With these design advantages, the device is being used more frequently [16]. As with any prosthetic implant, the need for removal or revision might occur, whether the result of implant failure, periprosthetic fracture, infection, or local recurrence. The optimal removal technique would preserve as much host bone as possible to facilitate subsequent revision. Amputation above the prosthesis remains an option; however, maintaining the maximal possible length of an amputation stump is advantageous for patients in terms of function and oxygen consumption demands [8, 9, 17, 19, 23].

Removal of traditional stemmed implants often requires morbid and technically demanding surgeries that involve extended osteotomies, tedious cement removal, high blood loss, and complex revision techniques [13]. However, the unique design of the components and the large mechanical forces exerted by the device in vivo require special techniques that allow preservation of host bone and facilitate implant removal during amputation or revision.

We report our techniques for implant removal, reasons for explantation, and the amount of bone loss associated with the excision technique and postoperative complications and ambulatory status of patients after revision surgery.

Surgical Technique

Indications for implant removal include infection, loosening at the bone-prosthetic interface, treatment of local recurrence, and periprosthetic fracture. In general, removal of the device involves: (1) release of compression; (2) disengagement of the spindle plate from the bone interface; (3) removal of transfixation pins from the anchor plug; and (4) extraction of the anchor plug. In most situations, these techniques can be performed without difficulty. However, unique problems encountered at each step can complicate an otherwise simple procedure. In the most common scenario, release of compressive forces can be achieved simply by exposing the compression nut in the device spindle and loosening it off the Bellville washers (Fig. 3). We prefer to screw in a compression plug before

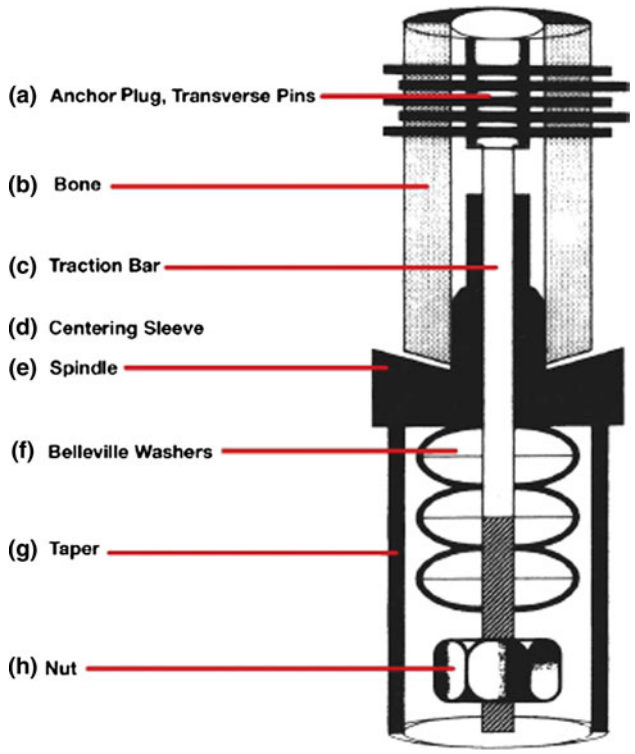

Fig. 1 A component diagram of the Compress® device shows Belleville washers stacked in series generating compressive load. (Reprinted with permission from Avedian RS, Goldsby RE, Kramer MJ, O'Donnell RJ. Effect of chemotherapy on initial compressive osseointegration of tumor endoprostheses. *Clin Orthop Relat Res*. 2007;459:48–53.)

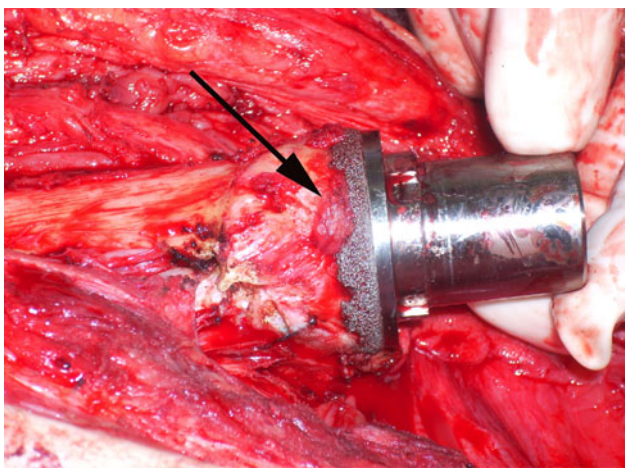

Fig. 2 An intraoperative photograph shows the proximal femoral bone with hypertrophic ingrowth into the porous surface interface of the device (arrow), which is attached to a distal femoral replacement prosthesis.

nut removal to prevent the washers from falling into the surgical field. If desired, the plug can be screwed down completely, which will release the compression and obviate the need for nut removal.

When access to the compression nut is not possible either because there is recurrent tumor blocking the surgical dissection around the prosthesis or the taper adapter cold welds to the spindle apparatus, alternative techniques for compression release must be used. In such cases, an approximately 2- to 5-mm ring of bone should be cut from the distal end of the existing femur at the bone-prosthesis interface using a saw or high-speed cutting tool. The ring of bone is cut away sequentially until only a small portion is left between the native femur and the compression plate (Fig. 4). When the final portion of bone is cut, there will be a visible and audible change in the position of the spindle as it collapses into the newly created space (the space previously occupied by the ring of bone, which has been removed). This completely relieves all the compressive forces and allows the transfixation pins to be extracted. The osseointegrated bone-implant interface can be disrupted by using an osteotome, a Gigli or oscillating saw, or a matchstick burr. With the compressive load off and the spindle freed from bone ingrowth, the device can be extracted from the host bone leaving only the anchor plug and transfixation pins remaining.

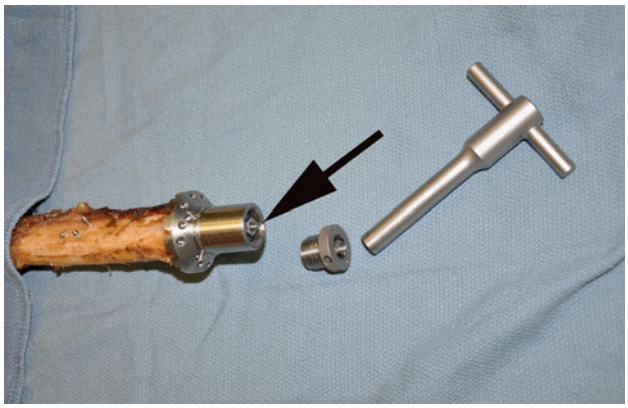

Fig. 3 This photograph taken in the laboratory shows the underside of the spindle, revealing the compression nut (arrow).

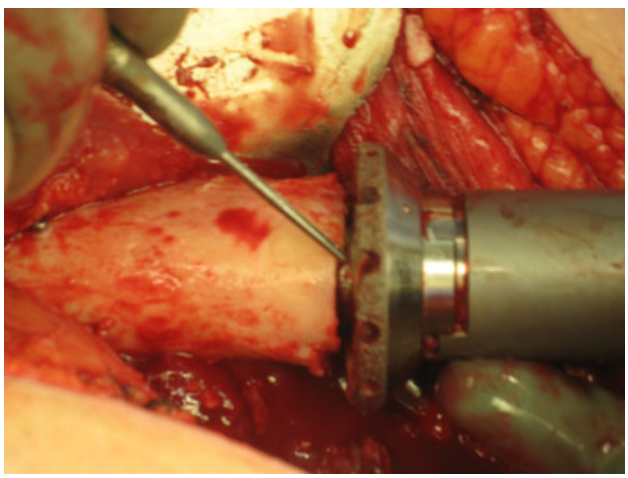

Fig. 4 An intraoperative photograph shows the use of a pencil tip burr to remove approximately 3 mm of interface bone to relieve compressive forces when the nut is not accessible.

Several techniques can be used to remove the transfixation pins. When the transfixation pins are readily visible without substantial host bone overgrowth, removal may proceed by simply using the threaded extraction device (available in the Compress® Anchor Plug Extraction Set; Biomet Inc) and tapping them out in the same direction in which they were inserted (Fig. 5). However, the exposed threaded end of the pin is fragile and often damaged if pin exposure and removal of bone overgrowth on top of the pins is needed. The surgeon therefore should be ready to extract them with standard pliers, needle-nose pliers, or vise grips if needed.

An alternative method for extracting the pins without damaging or deforming them is to insert a Kirschner wire into the head of the pin and then tap the pin through and out the opposite side of the bone. Care must be taken with anatomic structures in the pathway of the emerging pins (Fig. 6). Surgeons inserting these pins at the index operation should orient them in a manner that facilitates easy antegrade or retrograde removal.

Once the transfixion pins have been removed, the next task is extraction of the anchor plug. In our experience,

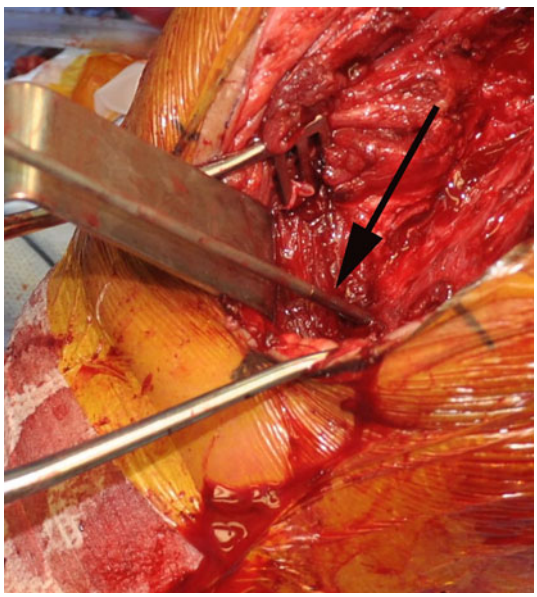

Fig. 5 An intraoperative photograph shows the use of the threaded extraction device (arrow) to remove the transverse pins.

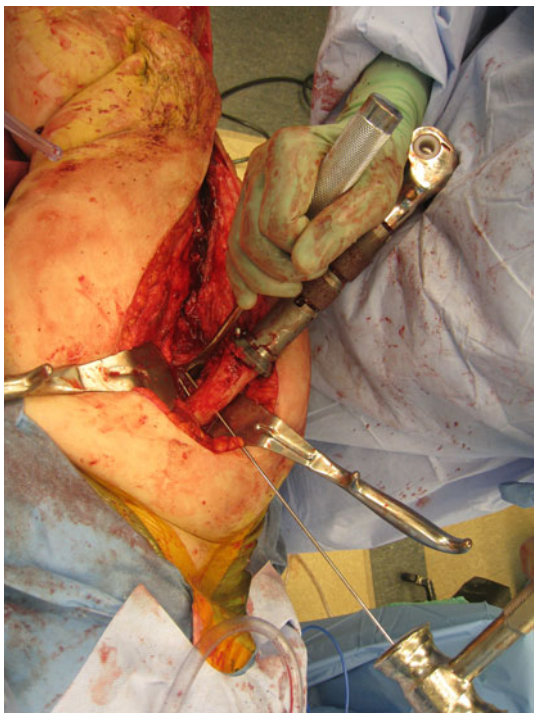

Fig. 6 An intraoperative photograph shows additional technique of transverse pin removal by tapping them through with the use of a wire. Protection of soft tissue structures on the backside of the pins is obtained using a Cobb elevator.

approximately half of the cases proceed in such a manner that the anchor plug can be removed by simply grasping it with pliers or vise grips and pulling it out. In the remaining cases, intramedullary bone growth between the anchor plug and spindle-centering sleeve blocks extraction of the anchor plug. Should the anchor plug not be easily removed with traction, an attempt can be made to use curettes to remove the intramedullary bone blocking the anchor plug. If the anchor plug does not pull out immediately, place a small Kirschner wire by hand through one of the traction pinholes to prevent the anchor plug from migrating deeper into the canal during bone removal efforts**.** When these bone removal techniques are not sufficient, the surgeon can grasp the traction bar with vise grips, tighten down a nut next to the vise grips to act as a stop, and then attempt to mallet out the anchor plug (Fig. 7). If this is still not successful, hollow or trephine reamers (available in the extraction set) slightly larger in diameter than the anchor plug may be used to overream the anchor plug (Fig. 8). Pulling on the traction bar then will release the anchor plug.

If the revision trephines are not available or the traction bar has broken, another method of removal involves cutting out a one-fourth to one-third circumference bone window starting at the anchor plug and then cutting distally (Fig. 9). This gives direct access to the intramedullary bone

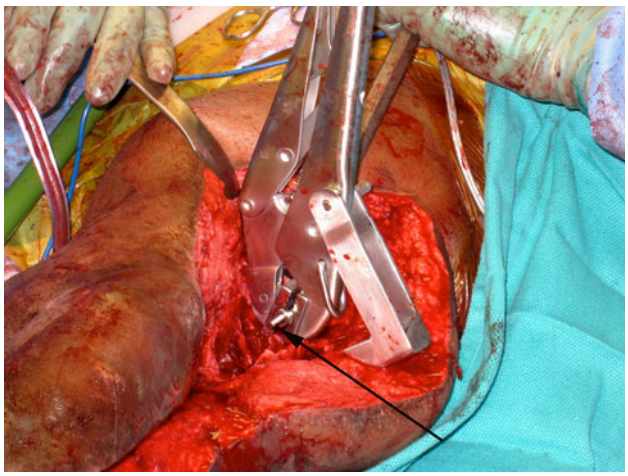

Fig. 7 An intraoperative photograph shows application of a vise grip to the traction bar (arrow) in preparation to manually remove the anchor plug using a mallet against the vise grip.

Fig. 8 From left to right, shown are the anchor plug, trephine, and bushing for the traction bar, which are included in the Biomet Compress® revision tray. (Published with permission from Biomet Inc, Warsaw, IN, USA.)

(Fig. 10), allowing it to be removed under direct observation (Fig. 11). The bone window then can be replaced directly and held in position with circumferential wires, cables, or a small plate, thus preserving bone length. In cases of traction bar breakage, the trephine reamer or cortical window techniques still can be used after placement of a Kirschner wire through a traction pinhole to prevent anchor plug migration.

Patients and Methods

After Institutional Review Board approval, our medical institution's electronic medical records system was used to retrospectively review the records of all 63 patients who received the device from January 1996 through January 2011. Inclusion criteria were (1) placement of the device at

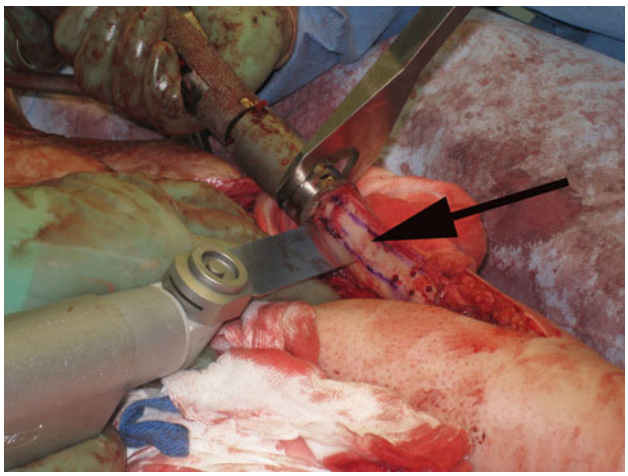

Fig. 9 An intraoperative photograph shows the creation of a bone window (arrow) to remove a fixed anchor plug. The cortical holes where the previous transfixation pins were have been removed. This gives direct access to the intramedullary bone so it can be removed under direct vision (Fig. 10).

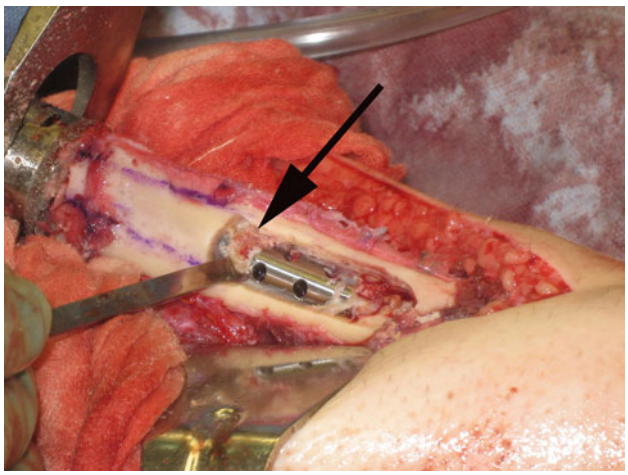

Fig. 10 An intraoperative photograph shows the creation of a cortical window and removal of bone between the centering sleeve and anchor plug (arrow) to facilitate anchor plug removal.

any institution; (2) removal of the prosthesis at our institution by the two senior authors (DM, RA); and (3) adequate medical records to complete clinical data collection.

We identified 11 patients (six males, five females) who underwent removal and/or exchange of their existing device during the stated period. Their average age was 47 years (range, 16–81 years). The average time from index device placement to revision and/or removal was 847 days. The most common cause of explantation was infection (eight cases) (Table 1), with the involved organisms being coagulase-negative staphylococcus (two cases), methicillin-sensitive Staphylococcus aureus (one case), methicillin-resistant Staphylococcus aureus (one

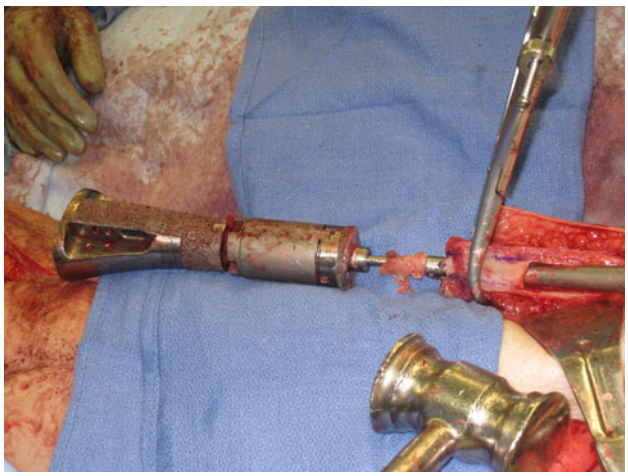

Fig. 11 An intraoperative photograph shows extraction of the anchor plug of a tibial prosthesis using a tamp and mallet after creation of a cortical window over the anchor plug.

case), Streptococcus viridans (one case), Pseudomonas aeruginosa (one case), combined Klebsiella pneumonia/Escherichia coli (one case), and Candida albicans (one case). The most common underlying tumor diagnosis was osteosarcoma (five patients) (Table 1). The minimum followup was 1 month (average, 20 months; range, 1–80 months; median, 15 months). No patients were lost to followup.

Followup included clinic visits at 2 weeks, 6 weeks, 12 weeks, 24 weeks, and then every 6 months for up to 5 years. A history and physical examination and radiographs of the involved extremity were taken to investigate for any signs of tumor recurrence or device complications.

Data recorded included age, sex, tumor diagnosis, tumor location, Musculoskeletal Tumor Stage (MSTS), whether the patient received chemotherapy and/or radiation, time from index device placement to resection, reason for explantation, organism involved if an infection was present, technique of device removal, length of host bone removed (intraoperative measurement with a ruler), complications, ambulatory function after device removal, subsequent procedure(s), and followup duration.

Results

At the most recent review, no patients had died of their disease and all patients were ambulating on either their salvaged extremity or a prosthesis. Two patients underwent combined chemotherapy and radiation during their treatment course, five with chemotherapy only and one patient with radiation only. Three patients underwent above-knee amputation at the time of device removal, whereas the others underwent continued limb salvage procedures (Table 1).

Table 1. Demographic data

Patient number	Diagnosis	Location	MSTS Stage	Explant reason	Compression relief	Transfix removal	Anchor plug removal	Host bone removed	Procedure after explant
1	Failed TKA	Proximal femur/ distal tibia	–	Infection	Ring cutout	Tap out with Kirschner wire, vise grips, pin extractor	Tap out femur, cortical window tibia	4 mm	AKA with augment
2	Parosteal osteosarcoma	Distal femur	Ia	Infection	Ring cutout	Pin extractor	Bone tamp only	10 mm	AKA
3	Pleiomorphic sarcoma	Distal femur	IIb	Infection	Manual turning of nut	Pin extractor	Cortical window	< 2 mm	Stemmed prosthesis implanted
4	Giant cell tumor	Distal femur	3	Infection	Manual turning of nut	–	–	8 cm	New Compress® implanted
5	Osteosarcoma	Distal femur	IIb	Infection	Manual turning of nut	Pin extractor	Cortical window	< 2 mm	AKA
6	Myxoid liposarcoma	Distal femur	IIb	Aseptic loosening	Manual turning of nut	Pin extractor	Burr within canal	< 2 mm	Stemmed prosthesis implanted
7	Osteosarcoma	Distal femur	IIb	Infection	Manual turning of nut	Pin extractor	Burr within canal	< 2 mm	New Compress® implanted
8	Pleiomorphic sarcoma	Distal femur	IIb	Aseptic loosening	Manual turning of nut	Pin extractor	Burr within canal	< 2 mm	Stemmed prosthesis implanted
9	Synovial sarcoma	Proximal femur, acetabulum	IIIb	Infection	Manual turning of nut	Pin extractor	Curette within canal	< 2 mm	New Compress® implanted
10	Osteosarcoma	Proximal femur	IIb	Infection	Manual turning of nut	Pin extractor	Curette within canal	< 2 mm	Antibiotic spacer placed
11	Osteosarcoma	Distal femur	Ia	Aseptic loosening	Manual turning of nut	–	–	< 2 mm	Baseplate revision

MSTS = Musculoskeletal Tumor Stage; AKA = above-knee amputation.

The average length of bone removed during explantation of the device was 8.6 mm (3 mm or less to 80 mm; median, 0 mm). Excluding the one patient with 8 cm of bone resection, the average decreased to 1.4 mm. For the patients who did not undergo amputation, the average length of bone removal was 3 mm or less.

There were no complications directly related to the bone-prosthetic interface. Four patients experienced other complication(s) after device removal/revision. The complications included irrigation and débridement for wound breakdown (two patients), latissimus free flap (one patient), and hip dislocation (one patient).

Discussion

Circumstances that may require removal of the device include local tumor recurrence, infection, periprosthetic fracture, or implant failure (Fig. 12). This endoprosthesis achieves bone prosthetic stability by using compliant compression through a short traction bow device. Unlike traditional stemmed implants that may require long osteotomies and relatively morbid operations for implant removal and revision, the device can be removed with little bone loss and revised with the same techniques used for primary surgeries. However, unique problems may be encountered during implant removal, and there are no descriptions of how to manage these surgical challenges in the literature. We discuss some of the special techniques that can be used for removal of the device that facilitate host bone preservation and revision of the endoprosthesis. We also present our experience with a series of 11 patients.

There are several limitations with our study. First, given the device is relatively new, we can report on only a small number of patients. Second, functional outcome data according to recognized outcome tools such as the MSTS or Toronto Extremity Salvage Score were not recorded and therefore we are not able to provide that information. Even if we did have this information, our study is too small and with too heterogeneous of a patient population to draw any meaningful functional outcome conclusions. Finally, the data included in our investigation might be subject to medical record errors and omissions, if present.

In any revision or amputation surgery involving removal of arthroplasty or endoprosthesis components, maintenance of host bone and limb length is of critical importance. Our technique takes into account the importance of host bone preservation. In our case series, the maximum amount of bone resection in patients undergoing device removal (versus amputation above the prosthesis) was 10 mm, with seven patients having less than 3 mm of bone loss. Specifically, this technique allows disassembly of the prosthesis at the bone-prosthesis interface rather than resection of the prosthesis through an osteotomy above the spindle. This allows the surgeon to maintain 8 cm or more of host bone and preserve residual limb length.

Preserving residual limb length has some benefits. For the surgeon, it increases the options available should additional limb salvage be attempted. With increased host bone length available, the surgeon has the option of not only

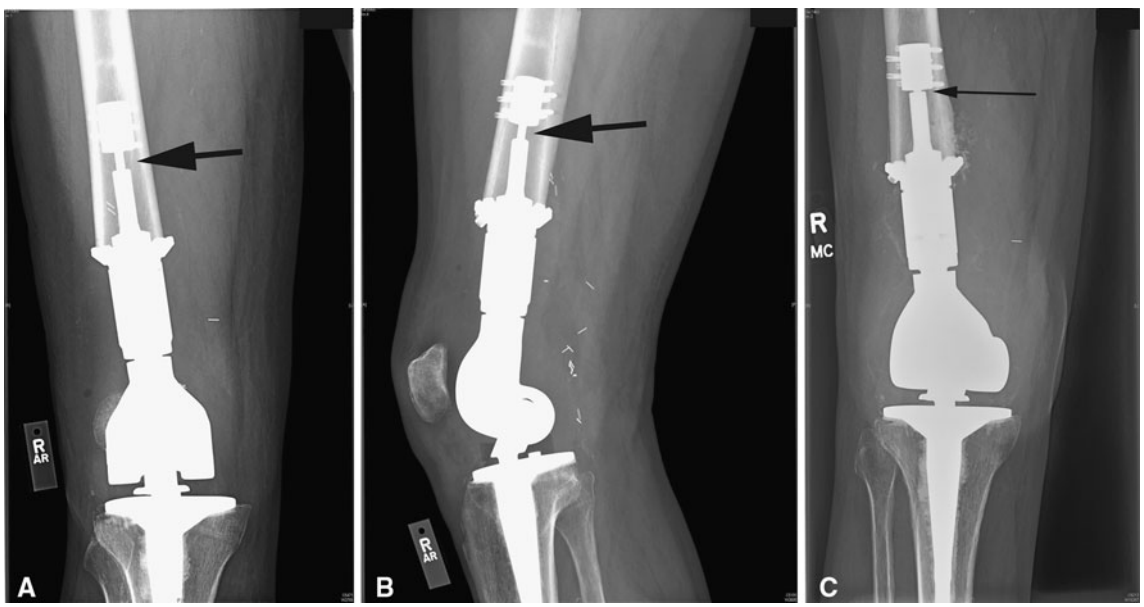

Fig. 12A–C (**A**) AP and (**B**) lateral radiographs were obtained of the knee of a patient after the index Compress® placement. The distance between the centering sleeve and the traction bar (indicated by the arrows) can be seen. (**C**) An AP radiograph obtained of the knee of the same patient at 6 months followup shows narrowing of the space between the centering sleeve and traction bar (arrow), indicating loosening and ingrowth failure. This patient underwent removal of the device for aseptic loosening.

implanting another Compress® device, but also moving to either cemented or press-fit intramedullary implants. With only short segments of bone remaining, intramedullary implants may not be an option because of poor fixation. It is particularly important to consider cemented, stemmed implants in patients who experience aseptic loosening of their device because of host bone compromise resulting from chemotherapy or radiation. In these cases, cemented, stemmed implants provide additional fixation when bone ingrowth onto the prosthesis cannot be reliably achieved.

In addition, preservation of host bone has important implications for metabolic demands of patients and prosthesis fitting. Waters et al. investigated various factors for patients with above-knee, below-knee, and Syme amputations [23]. They found gait velocity was greater and metabolic demand was less in patients with more distal amputations [23]. Another investigation of amputees with midfoot, Syme amputations, below-knee, through-knee, and above-knee amputations found normal walking speed and cadence decreased and oxygen consumption increased with more proximal amputation levels [19]. This study concluded that at more proximal amputation levels, the capacity to walk short or long distances is greatly impaired. Furthermore, additional stump length in patients undergoing amputation may lead to improved prosthetic fitting and/or additional prosthesis options.

In cases in which additional osseous length is desired even after use of these techniques, autograft or allograft augmentation is a viable alternative to preserve femur length for standard prosthesis fitting [14]. Additional methods of preserving length include the use of free fibula grafts, with or without additional allograft, to obtain additional bone length when a short bone segment is expected after sarcoma resection [3, 4, 24].

The device uses a unique design to achieve compression over a short bone segment. This design necessitates a unique approach when the prosthesis requires removal to maximize patient bone preservation. The techniques described in this article allow maximal preservation of host bone, therefore decreasing metabolic demand and improving functional status. Should removal of the endoprosthesis be required, osteotomy above (or below) the anchor plug can be performed, but this requires removal of an additional 8 cm to 13 cm of host bone versus less than 3 mm using the techniques we described. Alternatively, should the nut or transfixation pins be difficult to remove or the anchor plug blocked by intramedullary bone overgrowth, the techniques we presented allow for removal of the prosthesis with resection of a minimal amount of additional host bone.

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