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# Compress® Periprosthetic Fractures

## Interface Stability and Ease of Revision

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**Abstract** Periprosthetic fractures after massive endoprosthetic reconstructions pose a reconstructive challenge and jeopardize limb preservation. Compressive osseointegration technology offers the promise of relative ease of prosthetic revision, since fixation is achieved by means of a short intramedullary device. We retrospectively reviewed the charts of 221 patients who had Compress® devices implanted in two centers between December, 1996 and December, 2008. The mean followup was 50 months (range, 1–123 months). Six patients (2.7%) sustained periprosthetic fractures and eight (3.6%) had nonperiprosthetic ipsilateral limb fractures occurring from 4 to 79 months postoperatively. All periprosthetic fractures occurred in patients with distal femoral implants (6/154, 3.9%). Surgery was performed in all six patients with periprosthetic femur fractures and for one with a nonperiprosthetic patellar fracture. The osseointegrated interface was radiographically stable in all 14 cases. All six patients with periprosthetic fracture underwent limb salvage procedures. Five patients had prosthetic revision; one patient who had internal fixation of the fracture ultimately underwent amputation for persistent infection. Periprosthetic fractures involving Compress® fixation occur infrequently and most can be treated successfully with further surgery. When implant revision is needed, the bone preserved by virtue of using a shorter intramedullary Compress® device as compared to conventional stems, allows for less complex surgery, making limb preservation more likely.
**Level of Evidence:** Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.
Each author certifies that his or her institution has approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
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## Introduction

Given the increasing number of primary and revision arthroplasty cases performed, the prevalence of uncemented devices, the improvements in implant survivorship, and an active but aging patient population with attendant comorbidities such as osteoporosis, periprosthetic fractures are an increasingly common complication [4]. The incidence of periprosthetic femoral fractures around total hip and knee replacements has been estimated at 4.1% and 2.8%, respectively [3, 16, 17, 38]. A recent review concluded, however, "There is little information about the overall incidence (the risk) of periprosthetic fracture in a broader perspective, taking, for example, time since operation into account" [24]. Furthermore, treatment algorithms are often quite complex [26], and little has been published regarding treatment outcomes.

Comparatively less is known about the incidence and results of periprosthetic fractures around massive endoprosthetic implants typically used for limb salvage

performed for tumors. Although a recent report cited distal femoral and proximal tibial periprosthetic fracture rates of 0.9% and 2%, respectively [20], the literature provides little guidance regarding management and expected outcome of such fractures. For conventional cemented and uncemented devices, revision is complicated by excessive stem length and consequent sacrifice of bone stock in patients who frequently have high activity demands and a long life expectancy.

Compressive osseointegration technology was devised to provide stable fixation of endoprostheses by way of a novel spring-loaded system anchored by a short intramedullary device [2, 5, 9, 11, 23, 30]. Some concern existed that the Compress® implant would potentially be subject to an increased risk of periprosthetic fracture particularly at the transverse pin placement sites. Furthermore, it was thought that any torque load sufficient to cause a periprosthetic fracture would also result in disruption of the bone-prosthetic interface. Initial prosthetic survivorship results nonetheless have been encouraging when distal femoral Compress® implants were compared with conventional cemented stems [5]. As our experience with the Compress® device has developed, we have noted that the design allows for relatively straightforward revision in cases of infection or periprosthetic fracture [30].

Our purposes were to determine: (1) the frequency of ipsilateral limb fractures associated with Compress® implants; (2) whether they were periprosthetic or nonperiprosthetic; (3) time to fracture; (4) how they were treated; and (5) the effect of these fractures on prosthetic retention, maintenance of limb salvage, and ambulatory status.

## Materials and Methods

We retrospectively reviewed the records of 221 patients who had Compress® devices implanted between December 1996 and December 2008 for patients with the following indications: primary oncology (165); revision oncology (33); revision arthroplasty (18); and post-traumatic reconstruction (five). The anatomic locations were as follows: distal femoral (154), proximal tibial (38), proximal femoral (23), distal humeral (four), and proximal humeral (two). All ipsilateral limb fractures were recorded, and classified as periprosthetic or nonperiprosthetic (defined as fractures not adjacent to the Compress® implant). The minimum followup for patients with periprosthetic fractures after fracture treatment was 14 months (median, 62 months; range, 14–94 months) and the minimum followup for nonperiprosthetic fractures was 4 months (median, 24 months; range, 4–89 months). No patients were lost to followup. We obtained prior Institutional Review Board approval.

Previously published methods of Compress® surgery were followed [30]. For any given primary or revision indication, an osteotomy through bone of normal quality was made perpendicular to the longitudinal axis of the bone. Triple reamers were utilized to ensure the diameter of the centering sleeve of the device was at least 2 mm larger than that of the anchor plug. Transverse pins measuring 4 mm longer than the bone diameter were implanted through bone of normal quality. Hydroxyapatite-coated spindles of short length and large diameter with 800 lbs. of force are now frequently chosen for the femur, while short, small, 600 lb. hydroxyapatite-coated spindles are selected for tibial cases; anti-rotation pins are generally not utilized. Care was taken to achieve a tight fit between the centering sleeve and the endosteal surface.

To minimize the risk of periprosthetic fracture or spindle failure through application of rotational torques, patients with femoral and tibial reconstructions were maintained at a strictly nonweightbearing gait protocol for six and twelve weeks, respectively. Thereafter, partial weightbearing was advanced 25% per week. Gentle active and active-assisted range of motion and strengthening (quadriceps sets and straight leg raising) exercises were begun immediately after surgery. Calcium and vitamin D were also routinely prescribed. Recreational pursuits more vigorous than hiking, bicycling, and swimming are strongly discouraged; high or repetitive impact activities and contact sports are not allowed [30].

Plain radiographs were obtained before discharge from the hospital, as well as at 2 and 6 weeks after surgery. Clinical and radiographic examinations were generally performed at 3-month intervals for the first 2 years after surgery, and at 6-month intervals thereafter. From the medical records we obtained the following demographic data: gender, age, surgical indications (primary or revision; tumor, arthroplasty, or trauma), and whether chemotherapy or radiation therapy was administered. Radiographs were examined to identify technical errors, evidence of implant breakage, or disruption of the bone-prosthetic interface. From the charts we recorded time to fracture, mechanism of fracture, fracture management, and outcome with respect to prosthetic retention, limb preservation, and ambulatory status.

## Results

Fourteen of the 221 patients (6.3%) had ipsilateral limb fractures. Six of these (2.7%) were periprosthetic and eight (3.6%) were nonperiprosthetic.

Among those with periprosthetic fractures, there were two male and four female patients with a median age of

24.5 years (range, 13-32 years). Five patients underwent Compress® reconstructions for tumors; one cancer patient underwent revision of a failed conventional stemmed device. Three patients received chemotherapy after Compress® surgery; none received radiation. Median time to fracture was 6 months (range, 2–20 months). All periprosthetic fractures occurred in association with distal femoral implants (6/154, 3.9%). Surgery was necessitated in all patients with periprosthetic fractures. Although revision was necessitated in one patient who sustained a fracture at the site of anti-rotation pin insertion (Fig. 1), four revisions were undertaken for the more common fracture pattern that occurred above the anchor plug (Fig. 2). One patient underwent open reduction and internal fixation (ORIF) (Fig. 3). The osseointegration site was intact in all cases. There were no instances of implant fracture. At last followup five patients retained their prostheses without further surgery and were walking without an assistive device; one patient ultimately underwent amputation for persistent infection (Table 1).

Among those with minor ipsilateral nonperiprosthetic fractures, there were five male and three female patients with a median age of 14 years (range, 10-29 years). Seven patients underwent Compress® reconstructions for tumors; one cancer patient underwent revision of a failed Compress® device. Except for this patient, all patients received chemotherapy after Compress® surgery; one received adjuvant radiation. Median time to fracture was 8.5 months (range, 4–79 months). Minor fractures occurred in five distal femoral (5/154, 3.2%) and three proximal tibial (3/38, 7.9%) cases. Fractures in this group included distal tibial (four), patellar (two), proximal tibial (one), and proximal fibular (one) locations. Median time to fracture was 7 months (range, 4–79 months). Only one patient, with a patellar fracture, required open reduction and internal fixation (Fig. 4). The remaining patients were treated nonoperatively. At last followup all prostheses were retained, and patients were able to walk without the need for assistive device. Despite forces sufficient to cause fracture, there were no cases of device breakage, and the

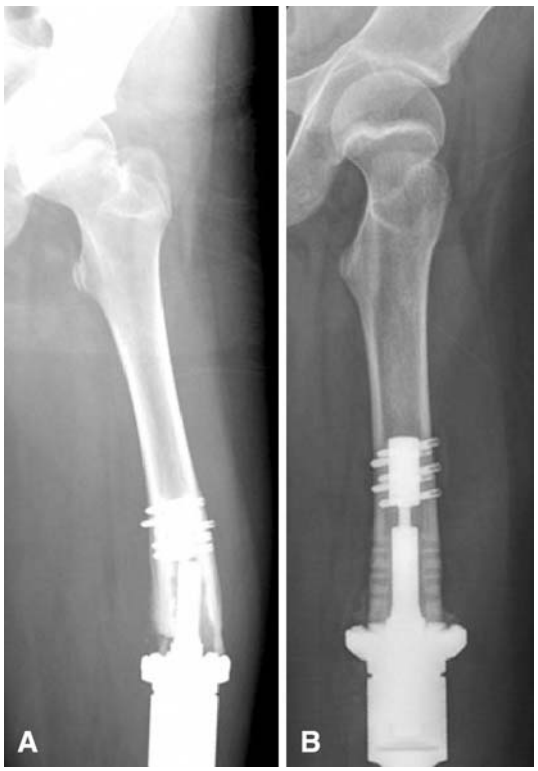


**Fig. 1A–B** (**A**) Preoperative and (**B**) postrevision radiographs of a 32 year-old man who sustained a periprosthetic fracture within two months after surgery while bearing full weight, contrary to instructions. (**A**) The cortical bone splintered where anti-rotation pins had been inserted into the cortex, just above the osseointegration site; intraoperative findings noted that the compression force had not been lost. (**B**) Revised implant after resection of an additional 4 cm of bone.

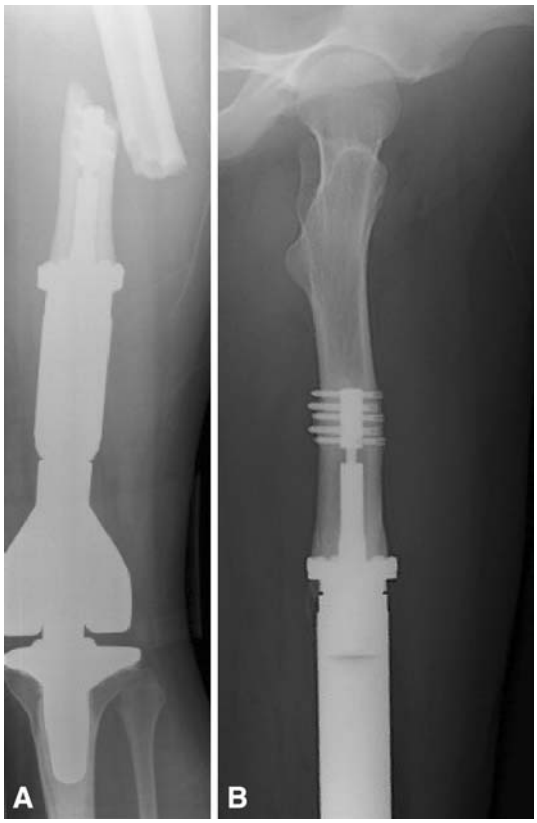


**Fig. 2A–B** (**A**) Preoperative anteroposterior and (**B**) 5.9 year postoperative lateral radiographs show a 17-year-old woman with a history of distal femoral osteosarcoma who sustained a displaced periprosthetic femoral shaft fracture 1.7 years after treatment with chemotherapy and Compress® reconstruction. (**A**) Despite the fracture, the osseointegrated interface remained intact. (**B**) Revision was accomplished in a straightforward manner by resection of a minimal amount of bone and reimplantation of a Compress® device.

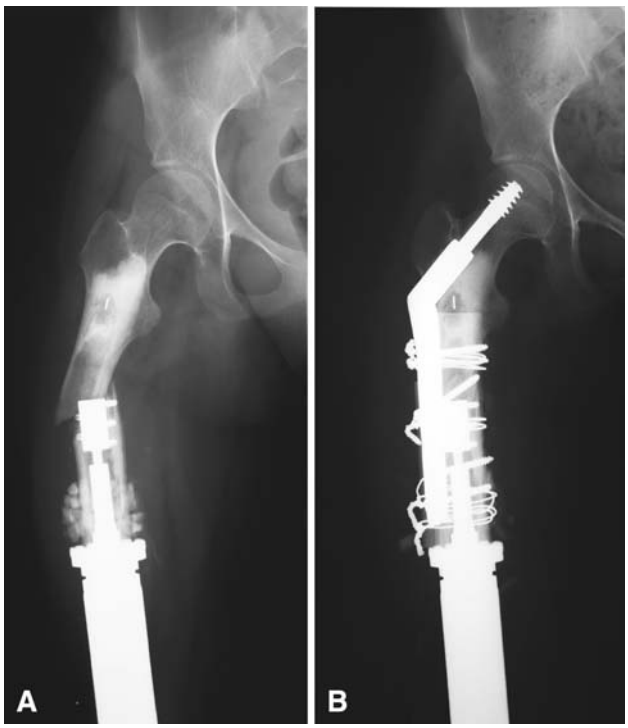


**Fig. 3A–B** (**A**) Preoperative and (**B**) postoperative anteroposterior radiographs of a 16 year-old woman with a periprosthetic femoral fracture occurring at an area of cortical thinning where an uncemented stem had previously been present. (**A**) The Compress® prosthetic-bone interface is stable. (**B**) Open reduction and internal fixation was undertaken without the need for prosthetic revision.

compressive osseointegration interface remained intact in all cases (Table 2).

## Discussion

We undertook this review to better understand the frequency, location, timing, and management of ipsilateral limb fractures associated with compressive osseointegration reconstructions. The effect of such fractures on prosthetic retention, limb preservation, and ambulatory status was also studied.

Limitations of this study include its size, length of followup, and focus on one type of endoprosthesis. The limited size and followup make it difficult to draw definitive conclusions regarding the time frame for fractures to occur. Experience with the Compress® device reported here is not directly applicable to periprosthetic fractures in arthroplasty patients, or even in the majority of tumor patients, who continue to receive conventional stemmed implants. Generalization of these results to centers less experienced in the use of compressive osseointegration techniques may not be immediately possible. Furthermore, the study population described here consists largely of young tumor patients, whereas the Compress® device is being increasingly used for revision arthroplasty patients, for whom advanced age and osteoporosis may well signal a higher periprosthetic fracture risk. Another limitation is the lack of firm data regarding risk analysis of periprosthetic fracture per patient-year [24]. However, the paper reports an experience of more than 200 patients treated over a 12-year period by four surgeons at two major sarcoma centers. In addition, the data would seem to confirm the acceptable risk profile of compressive osseointegration technology for endoprosthetic fixation with respect to the specific issues of periprosthetic fracture incidence, management, and prosthetic retention.

The most robust data regarding periprosthetic fractures from the arthroplasty literature deal with femoral fractures after total hip replacement, for which the 10-year probability of fracture has been estimated to be 0.64% [24]. The annual incidence is thought to vary between 0.045% and 0.13%, with a tendency for the incidence to increase over time [24]. Treatment is often complex [26], and the

**Table 1.** Compress® periprosthetic fractures

| Gender | Age at fracture | Indication | Compress® location | Adjuvant chemotherapy? | Adjuvant radiation? | Fracture location | Mechanism of fracture | Time to fracture (years) | Treatment | Followup after fracture (years) |
|---|---|---|---|---|---|---|---|---|---|---|
| F | 17 | Primary oncology | Distal femur | Yes | No | Proximal femur | Fall on wet rocks | 1.66 | Revision | 5.92 |
| M | 32 | Primary oncology | Distal femur | No | No | Proximal femur | Fall on cement | 0.17 | Revision | 5.55 |
| F | 30 | Primary oncology | Distal femur | Yes | No | Proximal femur | Fall from step | 0.58 | Revision | 4.8 |
| F | 13 | Primary oncology | Distal femur | Yes | No | Proximal femur | Fall from bus step | 0.91 | Revision | 1.49 |
| M | 29 | Primary oncology | Distal femur | No | No | Proximal femur | Mechanical fall | 0.42 | Revision | 7.8 |
| F | 16 | Revision oncology | Distal femur | No | No | Proximal femur | Mechanical fall | 0.17 | ORIF | 1.2 |

seriousness of this complication is highlighted by the 1-year mortality rate for such patients, which in one study was 12% for those undergoing revision arthroplasty and 33% for those undergoing ORIF [6].

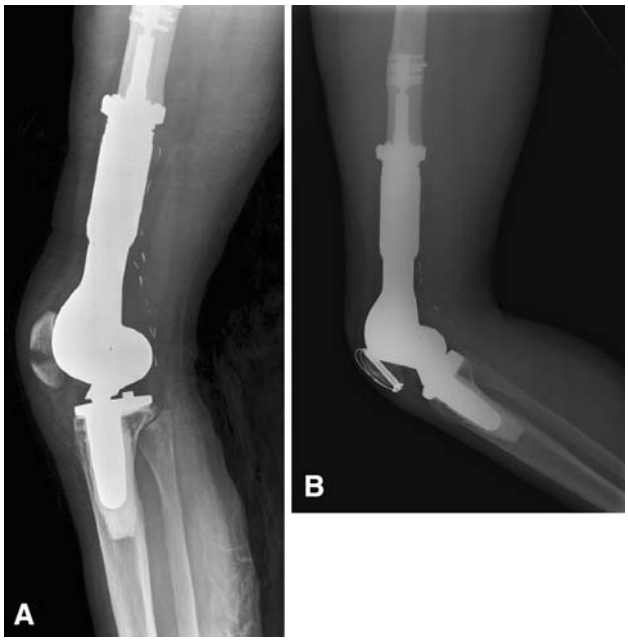


**Fig. 4A–B** (**A**) Preoperative and (**B**) 2.4 year postoperative lateral radiographs of an 18-year-old woman with a history of distal femoral sarcoma who sustained a displaced patellar fracture 3.8 years after treatment with chemotherapy, Compress® reconstruction, and radiation therapy are shown. (**A**) Despite a fall from a trampoline, the bone-prosthetic interfaced remained stable. (**B**) Healed fracture despite prior radiation is shown.

Comparable information regarding incidence, treatment, and outcomes for patients with periprosthetic fractures after megaprosthetic reconstructions, most often performed for tumors, is lacking. Most large series of intermediate to long-term results of endoprosthetic implants highlight implant survivorship, but failure due to periprosthetic fracture is often not specifically commented upon [7, 8, 12–15, 18, 21, 25, 32, 33, 36, 37]. Although Inglis and Walker reported a periprosthetic fracture rate of 37.5% of fixed hinge devices used to revise failed hinged implants [19], most recent papers commenting on periprosthetic fracture risk in primary tumor reconstructions using rotating hinge devices report rates of 0.3% to 6.1% (Table 3) [1, 10, 20, 22, 27–29, 31, 34, 35, 39]. Given the relatively low frequency of this complication, and the wide variety of

**Table 3.** Studies of periprosthetic fractures associated with endoprostheses

| Study | Periprosthetic fractures (%) |
|---|---|
| Ahlmann et al. [1] | 1/211 (0.5) |
| Capanna et al. [10] | 3/95 (3.2) |
| Jeys et al. [20] | 6/661 (0.9) |
| Kawai et al. [22] | 5/82 (6.1) |
| Mittermayer et al. [27] | 2/100 (2) |
| Mittermayer et al. [28] | 4/251 (1.6) |
| Morgan et al. [29] | 1/105 (1) |
| Orlic et al. [31] | 2/90 (2.2) |
| Torbert et al. [34] | 1/139 (0.7) |
| Unwin et al. [35] | 3/1001 (0.3) |
| Zeegen et al. [39] | 2/141 (1.4) |

**Table 2.** Compress® ipsilateral limb nonperiprosthetic fractures

| Gender | Age at fracture | Indication | Compress® location | Adjuvant chemotherapy? | Adjuvant radiation? | Fracture location | Mechanism of fracture | Time to fracture (years) | Treatment | Followup after fracture (years) |
|---|---|---|---|---|---|---|---|---|---|---|
| M | 14 | Primary oncology | Proximal tibia | Yes | No | Distal tibia | Fall from crutches | 0.58 | Cast | 3.17 |
| M | 14 | Primary oncology | Proximal tibia | Yes | No | Distal tibia | Fall from bicycle | 1.92 | Cast | 7.42 |
| M | 12 | Primary oncology | Distal femur | Yes | No | Distal tibia | Fall off of bed | 0.67 | Cast | 1.67 |
| F | 10 | Primary oncology | Distal femur | Yes | No | Distal tibia | Twisting injury | 0.58 | Cast | 0.67 |
| F | 18 | Primary oncology | Distal femur | Yes | Yes | Patella | Fall from trampoline | 3.75 | ORIF | 2.42 |
| F | 25 | Primary oncology | Distal femur | Yes | No | Patella | Fall at party | 6.58 | Cast | 1.08 |
| M | 29 | Revision oncology | Proximal tibia | No | No | Proximal fibula | Fall on ice | 0.33 | Brace | 2.92 |
| M | 10 | Primary oncology | Distal femur | Yes | No | Proximal tibia | Fall on wet floor | 0.75 | Cast | 0.33 |

implants reported upon, little has been described regarding optimal surgical management or treatment results of these fractures.

As compared to historical data regarding arthroplasty patients as well as cancer patients having conventional cemented and uncemented stems, we believe the Compress® device provides acceptable results in terms of the incidence of periprosthetic fractures in a generally young tumor population which is nonetheless subject to risk factors of osteoporosis (secondary to preoperative disuse and the effects of chemotherapy and radiation) and high activity demands. When a fracture does occur, Compress® technology offers the distinct advantage of comparatively straightforward revision, given the ease of extraction of the intramedullary portion of the device, and the minimal amount of bone (as little as 2 to 4 cm) that needs to be resected before implantation of a new device. Furthermore, short metaphyseal-epiphyseal fragments (43 mm or longer) remaining after fracture can still be salvaged with a short anchor plug, thus obviating the need for conversion to a total femoral replacement [30]. Although femoral fractures above the anchor plug can be expected to occur at any time in the patient's life if sufficient force is applied, our finding that all periprosthetic fractures occurred within 2 years of surgery is of potential importance for predicting the risk of this complication, since the opposite is expected to be true for typical arthroplasties and megaprostheses [24]. This difference can be attributed to the cortical hypertrophy engendered by compressive osseointegration forces; as demonstrated by Avedian et al. [2], the Compress® device provides, stability and bone growth at the prosthetic interface over the first 6 to 12 months, effectively sealing the endosteal canal to particulate debris [23, 30]. By contrast, stress shielding and osteolysis are expected to be ever-increasing problems for many tumor megaprosthetic stems, thereby increasing the risk for aseptic loosening and periprosthetic fracture with time. Finally, we observed no instances of mechanical breakage of the Compress® device, a finding that should be considered when comparing conventional endoprosthetic devices, for which implant fracture has been reported to be as high as 10% [14]. Although case-matched cohort studies are of some utility in comparing compressive osseointegration technology to standard stem fixation [5], long term prospective studies are desirable in order to elucidate this and other complications before any particular reconstructive approach can be definitively endorsed.



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