Management of Periprosthetic Femoral Fractures After Total Knee Arthroplasty Using a Distal Femoral Allograft

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Abstract: This study is a review and discussion of 12 consecutive patients who were revised with a distal femoral allograft for periprosthetic supracondylar fractures of the femur associated with poor bone quality by the same surgeon between 1990 and 2001. Two were lost to follow-up. The average age was 65 years, and the mean follow up was 6 years. Charts were reviewed to identify complications and graft survivorship. Functional assessment consisted of the modified Hospital for Special Surgery (HSS) knee score and the MOS 36-ITEM Short Form Health Survey. Radiographs were evaluated by 3 independent observers to determine graft union, resorption, and component loosening. The average postoperative HSS score and SF-36 were 75 and 88, respectively. Mean flexion was 100°. Nine patients achieved union and were able to fully bear weight. Three patients required more surgery as a result of postoperative complications. Radiographs showed no migration, no loosening, and good interface union in 9 of the 10 patients available for follow-up. We concluded that this is a viable salvage procedure for this type of injury. **Key words:** periprosthetic fracture, revision arthroplasty, total knee arthroplasty, allograft, supracondylar fracture.

The incidence of supracondylar fractures above total knee arthroplasty (TKA) is between 0.3% to 2.5% [1–9]. The number of periprosthetic femoral fractures is expected to increase as a result of the increased number of TKAs that have been performed over the past several decades. Most fractures occur following low-energy trauma and are associated with risk factors such as osteopenia, neurologic disorders [10], revision arthroplasty [7], anterior femoral notching [11], and both septic and aseptic loosening [4,8].

Fracture management poses a significant challenge in these cases because of the quality of the surrounding bone and the fixation of the prosthesis. In addition, for fractures located in close proximity to the femoral component, adequate fixation is difficult to obtain. Complications of fracture treatment have been reported to range from 25% to 75% [1,2,4,7]. In cases with severe comminution or segmental bone loss, osteosynthesis or conventional revision arthroplasty may not allow a stable construct, a tumor prosthesis or a rotating hinge prosthesis may be required.

To our knowledge, no previous study has reported on the use of a distal femoral allograft (DFA)

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Table 1. Patient Demographics

Case/Age/Sex	Reason for Primary TKR	Previous Surgeries	Cause of Fracture	Implants
1/75/F	PTOA	3	Fall	PFC (Johnson & Johnson)
2/58/F	OA	1	Osteolysis	PFC (Johnson & Johnson)
3/44/F	RA	1	Osteolysis	PCA (Howmedica)
4/24/F	JRA	3	Fall	Insall-Burstein II (Zimmer)
5/71/F	RA	1	Manipulation	Insall-Burstein II (Zimmer)
6/53/F	OA	1	Fall	Insall-Burstein II (Zimmer)
7/62/F	RA	3	Fall	PFC (Johnson & Johnson)
8/63/F	RA	2	Fall	PFC (Johnson & Johnson)
9/79/M	OA	1	Fall	LCCK (Zimmer)
10/58/F	PTOA	3	Fall	LCCK (Zimmer)
11/75/F	PTOA	3	Fall	LCCK (Zimmer)
12/93/F	OA	4	Fall	PFC (Johnson & Johnson)
13/92/F	OA	1	Fall	Insall-Burstein II (Zimmer)

Abbreviations: PTOA, posttraumatic osteoarthritis; OA, degenerative osteoarthritis; RA, rheumatoid arthritis; JRA, juvenile rheumatoid arthritis.

and a revision TKA in the treatment of periprosthetic femoral fractures above a knee arthroplasty. We will review and discuss the functional and radiographic outcomes as well as the survivorship of this procedure.

Materials and Methods

Study Group

Data were obtained from a prospective database and a chart review of 12 consecutive patients who were treated with DFAs in conjunction with revision TKA for periprosthetic femoral supracondylar fractures by the same surgeon between 1990 and 2001 (Table 1). All patients with these fractures associated with poor bone quality were treated with DFAs at our institution. All fractures were classified according to the system proposed by Lewis et al, who distinguished 3 types. In Type I (undisplaced) and Type II (displaced) fractures, the prosthesis is stable, whereas Type III fractures consist of displaced or undisplaced fractures associated with a loose or failing prosthesis [12]. All fractures in this study were Type III. In addition, all patients had poor bone stock resulting from severe comminution, segmental bone loss, or marked osteoporosis, which prohibited conventional methods of treatment. A typical fracture is shown in Fig. 1. There were 12 female patients and 1 male patient. The mean age at the time of revision surgery was 65.1 ± 18.9 years (range, 24–93 years). Five patients had undergone primary TKA for degenerative osteoarthritis (OA), 3 for posttraumatic OA secondary to a supracondylar fracture, 4 for rheumatoid arthritis, and 1 for juvenile rheumatoid arthritis. The patients had had a mean of 2.07 ± 1.1 previous procedures (range, 1–4) before the revision surgery. Supracondylar fractures in 8 patients were caused by a fall; 3 had minor trauma; and 1 fractured her femur during manipulation under anesthesia. The implants included 4 press-fit condylar or total condylar-III prostheses (PFC or TC-III Johnson & Johnson Orthopaedics, Raynham, MA); 4 Insall-Burstein-II constrained condylar knee prosthesis (CCK; Zimmer), 1 porous-coated anatomic prosthesis (PCA; Howmedica, Rutherford, NJ), and 3 legacy con-

Fig. 1. Radiographs of the left knee of a 79-year-old man with a Type III supracondylar periprosthetic fracture.

strained condylar knee prostheses (LCCK; Zimmer, Warsaw, IN).

Clinical Evaluation

A prospective database established in 1990 was used to systematically review all cases of revision arthroplasty with a DFA for fracture. Additional chart reviews were performed to document all complications. Functional assessment was made on the basis of the modified Hospital for Special Surgery knee score (HSS) [13,14], which is based on subjective factors (pain, instability, use of walking aids, distance walked) and objective factors (extension block, degree of flexion, and the presence of an effusion). An excellent result was considered to be a score of 85 to 100, a good result was 70 to 84, a fair result was 60 to 69, and a poor result was <60. The MOS 36-ITEM Short Form Health Survey (SF-36) [15–17] also was completed by the patients. This is a reliable, validated generic instrument of health status designed to measure patient-perceived health along the dimension of physical functioning, role functioning, emotional and bodily pain, general health, vitality, social functioning, mental health, and health transition. Each dimension's raw score is converted to a 100-point scale, with the higher score signifying a lesser degree of disability. Results of the SF-36 were compared with the age- and sex-standardized specific scores of the Canadian population [18] using a 1-group *t*-test. It was not possible to obtain premorbid, modified HSS and SF-36 because all these fractures were secondary to an unexpected trauma.

Failure of the procedure was defined as a poor result on the HSS score or the need for an additional surgery that involved removal of the allograft.

Radiographic Evaluation

Patients were evaluated radiographically using anteroposterior (AP) and lateral views of the affected knee and 3-foot standing AP views of both legs. Union was defined as the presence of trabeculae bridging the host-allograft junction and obliteration of host-allograft junction on both AP and lateral radiographs. Definite loosening was defined by progressive radiolucent lines or by migration or fracture of the cement. Allograft resorption was classified as mild (partial-thickness loss of <1 cm in length in 1 cortex), moderate (partial thickness loss of at least 1 cm in 1 cortex), or major (full-thickness loss of any length in 1 cortex). The radiographs were assessed by 2 independent surgeons (κ=0.75, P = .02).

Surgical Technique

Radiographs of the contralateral knee were used to determine the size of the allograft required. An allograft with a smaller diameter than the host bone was selected so that it could be placed within the host cortical shell. In this manner, the host ligaments could be preserved. A smaller graft also permitted wound closure with decreased tension [19,20].

The allograft was harvested by an American Association of Tissue Banks–accredited institution [21], where it underwent radiation with 2.5 megarads and was stored at −70°C. The DFA was opened after removal of the implants from the patient, and it was determined that a revision without using the graft was not possible.

Two surgical teams were used during the case for optimal efficiency. One team prepared the allograft, making appropriate femoral cuts and cementing in a long-stemmed revision femoral component. The other surgical team removed the implants from the patient.

A midline skin incision and medial parapatellar arthrotomy was used to access the joint. When required for patellar eversion, a tibial tubercle osteotomy was performed. The tibial component was retained in cases in which it was solidly fixed and stable enough to support a polyethylene insert with maximal constraint. Cultures were taken from both the knee and the allograft to rule out any existing infection.

The implant was removed with the pseudomembrane, and the collateral ligaments and epicondyles were retained when possible. The remaining distal femur was step-cut with a minimal bone resection. On a side table, the DFA was instrumented and a step-cut was made to match that of the host femur (Fig. 2).

Care was taken to determine the appropriate level of the joint line so that cuts could be made in such a way as to avoid the tendency for joint-line depression in cases in which revision of the tibial component was required. Soft tissues were balanced to obtain equal flexion and extension gaps. The collateral ligaments were not always easy to identify, and in some respects, the entire soft-tissue sleeve was balanced. The femoral implant–DFA composite was trialed *in situ,* and the cuts were fine-tuned as required. On the back table, the femoral component was cemented into the DFA with a stem, which was long enough to extend to at least 2 cortical diameters above the graft-host junction. Care was taken during cementing to avoid getting cement on the interface between the graft and the

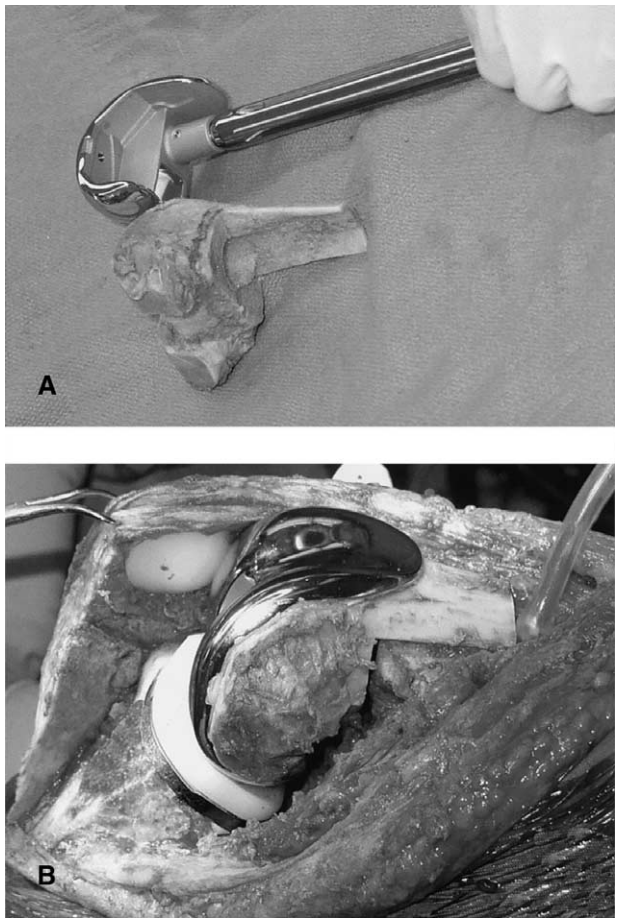

Fig. 2. (A) DFA preparation on a side table. (B) Implantation of the DFA composite.

host, which would interfere with the graft-host junction. Once the cement had set, the construct was implanted matching the 2 step cuts. The residual host femur, with its ligaments and other soft tissues attached, was wrapped around the allograft-host junction to serve as a living bone graft. Cortical strut allografts and cerclage wires were added to the construct when warranted for additional stability. Residual host bone was used as autograft at the DFA-host junction. We recommend the use of a constrained polyethylene insert in these cases. Postoperative radiographs were obtained in the recovery room (Fig. 3). Prophylactic antibiotics consisted of an intravenous first-generation cephalosporine for 5 days, followed by oral antibiotics for 5 days. If the patient was catheterized, gentamyacin was used for 24 hours, followed by Septra until the catheter was removed. Coumadin prophylaxis for venous thrombosis was routinely used for 3 weeks. Gentle active and passive range of motion was begun at 48 hours. For patients with knees in which a tibial tubercle osteotomy was performed, active extension exercises were delayed for 6 weeks. Weight-bearing was allowed when radiologic evidence of union was detected.

Results

Clinical Results

The results of the HSS questionnaire are summarized in Table 2. Preoperatively, none of the patients were able to bear weight on the affected limb. Of the 12 study patients, 2 patients were lost to follow-up because they had moved out of the province; however, they were doing well while they still were being followed. Of the 10 remaining patients, 9 were female and 1 was male. The mean age at the time of surgery was 60.4 ± 16.8 years (range, 24–79 years), and the mean follow-up was 58.8 months (range, 12–144 months). Three patients required a tibial tubercle osteotomy for adequate exposure. The postoperative mean modified HSS score was 74.7 ± 6.8 (range, 64–86) at the last follow-up. The mean range of motion was 97.7° ± 21.8° (range, 50°–115°) of flexion. According to our classification, 1 patient (10%) had an excellent result, 5 patients (50%) had a good result, 3 patients (30%) had a fair result, and 1 patient (10%) had a poor result.

The results of the SF-36 questionnaire are shown in Fig. 4. Comparison is made to the sex-standardized means of the normal Canadian population between the ages of 55 to 64 years [18]. The only statistically significant differences identified were lower scores in physical function and bodily pain ($P < .0001$ and $P = .025$, respectively) for the study group compared with the normal Canadian population.

Complications

Of the 10 patients, 3 needed additional surgeries as a result of postoperative complications. One patient (case 1) required a medial collateral ligament repair and polyethylene exchange for a larger size at 1 month postoperatively. The second patient (case 8), who had a history of diabetes, was diagnosed with an infection 13 months after surgery. This was treated with implant removal and arthrodesis using an intramedullary nail. Although her knee fused and she functioned well, 5 years later, she developed another infection and required an above-knee amputation. The third patient (case 7) required a second procedure 32 months' postoperatively. This consisted of a strut allograft, iliac crest

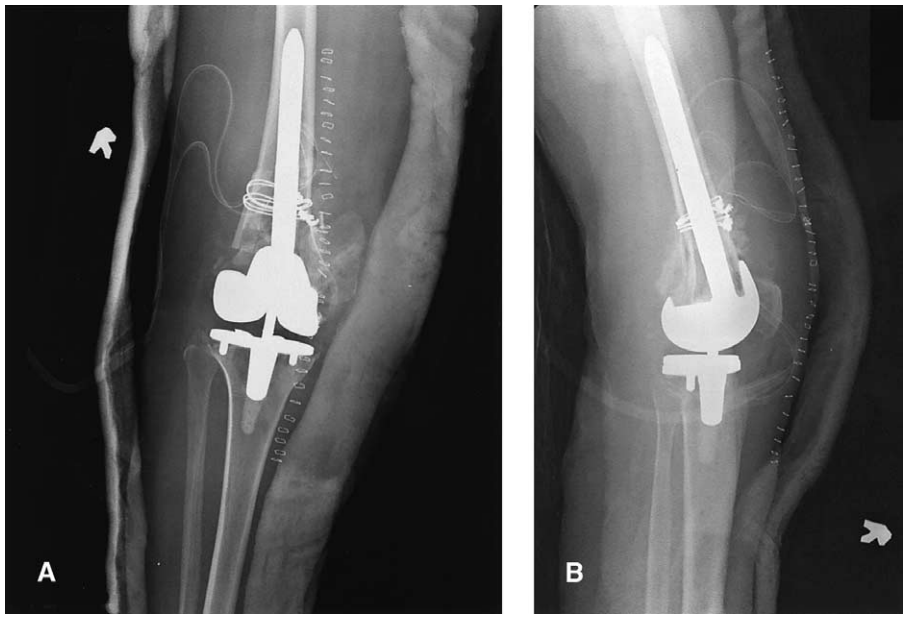

Fig. 3. Postoperative radiographs.

bone grafting, and fixation with a plate and screws, which ultimately resulted in union at the host-graft interface. The 2 patients who were lost to follow-up were doing well and were complication-free while still under our care.

Radiographic Results

All of the 10 study patients had radiographs available for analysis. Except the patient who had an amputation, all patients showed radiographic evidence of union between the host bone and the allograft at the latest follow-up. None of the patients showed radiographic evidence of implant loosening or migration of the component. Two patients had moderate resorption, 2 patients had mild resorption, and the remainder showed no resorption.

Survivorship

At a mean follow-up of 6 years, 9 of 10 patients were still functioning well. The patient who developed an infection and went on to amputation was the only graft failure in the series.

Discussion

Unstable supracondylar periprosthetic femur fractures in the presence of poor bone stock or severe comminution are difficult to treat with open reduction and internal fixation. When the fracture is associated with a loose component, revision arthroplasty is an option. However, this can be challenging because of large, contained and uncontained defects. Salvage procedures, such as

Table 2. Functional Results

Case	HSS Total	Pain	Instability	Walking Aids	Distance	Extension Block	Flexion	Effusion	Flexion Degrees
1	68	28	10	1	1	10	8	10	50
2	64	28	10	3	3	2	8	10	85
3	74	35	10	1	1	2	15	10	110
4	86	28	10	3	10	10	15	10	110
5	75	28	10	1	1	10	15	10	110
6	79	28	10	3	3	10	15	10	110
7	79	35	10	3	6	7	8	10	80
8	69	21	7	3	3	10	15	10	115
9	79	28	10	0	6	10	15	10	110
Mean	74.77	28.77	9.66	2	3.77	7.88	12.66	10	97.77

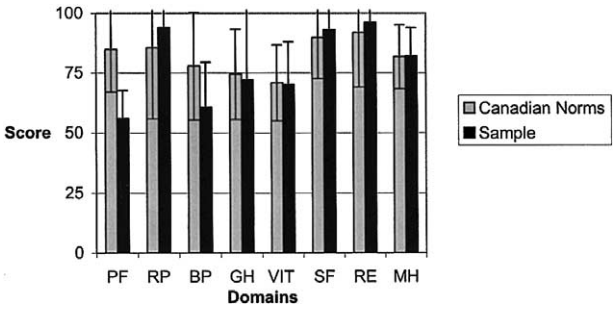

Fig. 4. Domain-specific SF-36 scores of patients who have undergone DFA compared with age- and sex-standardized Canadian norms for the population. PF, physical function; RP, role physical; BP, bodily pain; GH, general health; VIT, vitality; SF, social function; RE, role emotional; MH, mental health.

arthrodesis, cause severe leg-length discrepancy and poor functional results. Although defects of up to 2 cm can be reconstructed with implant augments, large defects must be reconstructed with custom implants or a revision TKA using a DFA.

Modular tumor prostheses are challenging for the surgeon, because, even with optimal imaging techniques, it is difficult to predict the exact degree of bone loss preoperatively. In addition, the femoral canal is violated by cement or a porous stem, as opposed to the smooth stem used with a DFA, making future revision more challenging. Furthermore, the metal prostheses do not provide adequate surfaces for ligament attachment.

Strut allografts can be used to reinforce cortical defects, for fracture fixation [22], or to bypass the DFA-host bone junction. They can be customized to fit the femur, and their mechanical properties resemble those of the host femur, thereby causing less stress shielding than plates [23]. In addition, they are implanted with wires or cables rather than screws, which can lead to local stress concentrations.

A major concern with the use of allografts is the risk of infection. Nonvascularized allografts can be a nidus for the growth of organisms [24]. We previously reported an increased risk of infection associated with the use of a DFA (8%) [20], compared with revision arthroplasty without allograft (0%–4.5%) [25–27]. This higher risk is confirmed by our rate of infection (10%). In reviewing Mankin's series of large structural allografts, Lord reported a 12% rate of infection [28]. Liberman and Tomford both reported similar rates of infection after revision arthroplasty with or without structural allografts [29,30], and Tsahakis reported no infections in a series of 19 allografts in revision knee surgery, despite having 3 patients who previously had been treated for infection [31]. Other potential disadvantages of allograft bone in revision arthroplasty include fractures and nonunion [20,32,33]. In this series, we report 1 case (10%) of nonunion that healed after subsequent bone grafting. Risk of late resorption has been reported by several groups [34,35], but not by others [36]. This series reports 4 cases of resorption (40%), of which 2 were mild. However, we found no correlation between resorption and functional results.

Allografts are physiologic and prone to unite to the host bone (Fig. 5). They allow surgeons to reproduce the anatomic shape of the distal femur and manage unexpected bone defects. Kraay [37] reviewed 7 patients in whom large-segment DFAs were used for supracondylar fracture above TKA. All femoral components were well fixed at a mean of 44 months. Postoperative instability, attributed to poor ligamentous healing, was a major problem.

Clatworthy [20] reviewed 52 patients in whom 66 structural allografts were used with a mean follow-up of 97 months. The survivorship of the allografts was 72% at 10 years, and 12 knees (23%) required revision. Dennis [38] reported 32 structural allografts followed for an average of 50 months. Good or excellent results were obtained in 86% of cases. Satisfactory results also were reported by Engh and Ghazavi at mean of 50 months [14,39]. Mnaymneh reported on 10 patients (7 DFA), of whom 2 were treated for supra-

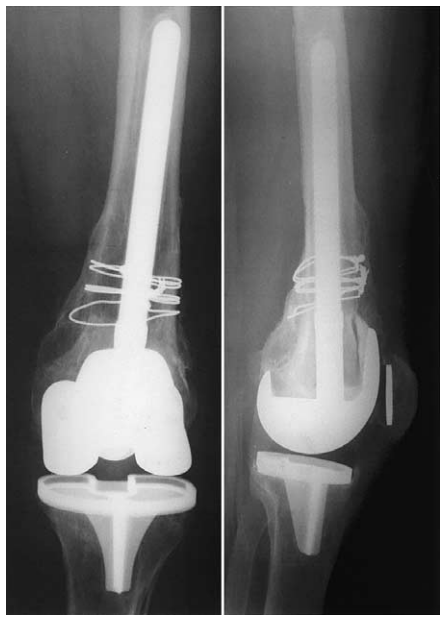

Fig. 5. Twelve-year postoperative radiograph showing graft incorporation.

condylar fracture above TKA, with a mean duration follow-up of 40 months. Five of the 7 femoral grafts united (70%). The average postoperative HSS score was 67, and the knees had an average range of motion of 92° [32]. This study reports a mean HSS score of 74.7, which was lower than that reported by Mow for DFA in revision arthroplasty (mean score, 86) [25]. Our rate of union (90%) was better than the 73% union rate of Mow [25]. His experience suggests that even if further revisions are necessary for a loose prosthesis, bone stock is improved by allograft incorporation.

The results of the present study are relatively short-term with regard to the assessment of structural allografts. However, they are encouraging, particularly when the difficulty of these reconstructions is considered, and fracture healing is a prime concern.

With regard to the SF-36 scores, the study patients scored significantly lower in the physical function and bodily pain domains compared with the general population. This finding is consistent with the fact that patients who have undergone revision TKA do not usually attain a level of function similar to the general population [18]. In addition, many of these patients have undergone several surgical procedures (mean, 2.01) before their revision with a DFA.

In summary, we believe that the use of DFAs is a good alternative for the treatment of comminuted periprosthetic fracture in elderly patients. It provides early stability, support for implants, restoration of bone stock, and fracture union.

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