

Two-Stage Reimplantation for the Salvage of Infected Total Knee Arthroplasty*

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ABSTRACT: The results of eleven two-stage reimplantations to salvage eleven infected total knee arthroplasties in ten women (seven with osteoarthritis and three with rheumatoid arthritis) were evaluated after an average follow-up of thirty-four months. The staged procedures included removal of all of the components of the prosthesis and all cement, then six weeks of parenteral antibiotic therapy (monitored by maintaining serum bactericidal levels at a peak dilution of 1:8), and finally reimplantation with a total condylar-type prosthesis. All antibiotics were discontinued after reimplantation.

At follow-up, no patient had had a recurrence of the original infection, but one had a hematogenous infection with a different organism secondary to an infected bunion. The results after reimplantation were rated excellent in five knees, good in four, and fair in two. Weakness of the extensor mechanism with an extension lag was the most frequent complication.

We do not believe that antibiotic therapy alone is adequate for the management of an infection around a prosthesis. The method described appears to be effective but it is costly and time-consuming. The surgical procedures and medical management are technically difficult, often special equipment and a custom-made prosthesis are required, and there are no shortcuts.

Infection after total knee arthroplasty has usually meant failure. As more total knee arthroplasties are performed the number of deep infections can be expected to increase even though the infection rates are declining.

What constitutes appropriate management of deep infection after total knee arthroplasty has been controversial. Reports of the salvage of infected arthroplasties have appeared in the literature, but often with no long-term follow-up. A review of the 1970's literature on total knee arthroplasty^{1-6,10-12,14,15,19-24,29-35,37,38} yielded reports of 140 deep infections after 2997 total knee arthroplasties. The reported infection rates ranged from none^{30,31} to 23 per cent²⁰, with the over-all rate being 5 per cent. After the salvage procedures in these 140 patients with an infected total knee arthroplasty the prosthesis was retained in forty-nine

(35 per cent), removed from sixty-five (46 per cent), and reimplanted in eleven (8 per cent). Amputation was carried out in seven patients (5 per cent), and eight patients (6 per cent) died.

However, the follow-ups were insufficient to yield detailed information about the long-term results and the quality of these results. The references in these studies to a stiff knee when the prosthesis had been retained, to fibrous ankylosis requiring bracing after removal of the prosthesis, and to attempted arthrodesis suggest that many of the patients had continuing problems. In a study of ten knees that had been treated by arthrodesis after an infected total knee arthroplasty, non-union occurred in three and fusion was achieved in the other seven after two to twelve months of immobilization¹⁶. In another study the authors reported on forty attempts at arthrodesis after infection, and in that series there were ten infected knees in which a previous attempt to salvage the prosthesis by débridement and antibiotic therapy had failed⁷. Over-all, thirty-four (84 per cent) of the forty knees had a successful fusion. In our own experience, after removal of a prosthesis because of infection the remaining bone stock has often been poor, making arthrodesis difficult or impossible. In addition, even a successful arthrodesis seldom produces a result that is satisfactory to the patient.

There is little information in the literature concerning reimplantation after removal of a total knee replacement for the treatment of infection. In one study there were nine attempts at reimplantation, of which four were followed by removal and arthrodesis¹¹. In another report one infected Attenborough total knee arthroplasty was salvaged by replacement using antibiotic-impregnated cement, but the length of follow-up was not reported³⁷. A patient in a third series had a two-stage salvage procedure that consisted of removing the prosthesis and filling the cavity with pellets of antibiotic-impregnated cement, followed by reimplantation, but only a six-month follow-up was reported in that case¹⁷. Despite many poor results, reimplantation after removal of an infected total hip arthroplasty has had some success^{8,9,13,18,25-28}.

In 1977, a prospective study was started by the senior one of us (J. N. I.) to evaluate two-stage reimplantation as a way to salvage an infected knee arthroplasty. The treatment protocol was divided into three phases: (1) débridement of the soft tissues and removal of the prosthesis and all cement, (2) six weeks of parenteral antibiotic therapy to treat the in-

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fection, under the supervision of one of us (B. D. B.) who is a member of the Infectious Disease Department, and (3) implantation of a new total knee arthroplasty. We are reporting our results with this protocol in ten patients treated between 1977 and 1979 who had follow-ups of two years or more (except for one patient who died of a myocardial infarct twenty and twelve months, respectively, after reimplantation in each knee).

Materials and Methods

During the five years between January 1977 and December 1981, twenty-seven patients with twenty-eight infected total knee arthroplasties were admitted to the Knee Service at The Hospital for Special Surgery. Ten of these patients were excluded from the described treatment protocol: eight because they either refused or were too infirm for such treatment and two because the infecting organisms (*Pasteurella multocida* in one and *Escherichia coli* and *Staphylococcus aureus* in the other) were not considered susceptible to antibiotic therapy since the dosage required to obtain bactericidal serum levels was likely to be toxic. The latter two patients had primary arthrodesis using a Hoffmann external fixator. In one the fusion was successful, but in the other the result was a fibrous ankylosis with 30 degrees of motion, requiring the use of a brace and one crutch. The other eight knees were treated by lifetime suppressive antibiotic therapy, with varying results. Two patients (three knees) died without overt signs of sepsis, one and two years after diagnosis of the infected arthroplasty. Two patients (three knees) had recurrent episodes of sepsis, and in one of them the infection spread to a total hip arthroplasty. Of the remaining two knees, one continued to be painful and the other required a high above-the-knee amputation because the sepsis was not controlled by the removal of a Guepar prosthesis and the tissues were devitalized and heavily impregnated with metallic debris. A subsequent infection of the stump in this patient necessitated a revision, but the wound eventually healed satisfactorily. When last seen, the patient was able to walk while wearing an above-the-knee prosthesis.

Thus, from 1977 through 1981, eighteen knees in seventeen patients were selected for salvage using the two-stage reimplantation protocol. Of these eighteen knees, eleven (in ten patients) were treated between 1977 and 1979. The seven knees (in seven patients) that were treated after 1979 were not included in this report because the follow-up was too short.

All ten patients in this study were women. Their mean age at the time of the index arthroplasty was 67.3 years (range, sixty to eighty-six years). The primary diagnosis was osteoarthritis in seven patients and rheumatoid arthritis in three (four knees). Three of the ten patients had had another operation on the knee prior to the arthroplasty: one, an unidentified operation forty years before the total knee arthroplasty and two, a medial meniscectomy followed by worsening symptoms. The average weight of the ten patients was 64.2 kilograms (range, forty-two to ninety-two

kilograms). None of the patients were diabetic at the time of the original arthroplasty, but in one adult-onset diabetes mellitus developed around the time that the deep infection occurred. Two patients had had prior injections of steroids into the knee, and another was given systemic steroids perioperatively at the time of the index total knee arthroplasty because of a recent history of systemic steroid therapy for rheumatoid arthritis. Four of the ten patients had had bilateral total knee arthroplasty. One of them had an infection in both knees and three, an infection in one knee. The infection involved five right knees and six left knees.

Five of the ten patients had had the index total knee arthroplasty performed elsewhere, and they were referred to us after the deep infection was diagnosed or suspected. Information on the perioperative management was not available for study in these patients. The other five patients (six infected knees) had the index total knee arthroplasty performed at The Hospital for Special Surgery, and their cases could be analyzed in detail.

In The Hospital for Special Surgery group (six knees in five patients), prophylactic antibiotics were always given at the time of the index arthroplasty. Two patients (three knees) received intravenous Keflin (cephalothin), one gram every six hours for forty-eight hours, and then oral Keflex (cephalexin), 500 milligrams four times daily for two days in one patient and for six days in the other. The remaining three patients received intravenous oxacillin, two grams every six hours for forty-eight hours; thereafter two of them received oxacillin orally, 500 milligrams four times daily for three days and seven days, respectively, and the third received no more antibiotics. (Our current program limits the administration of perioperative antibiotics to two days.)

Two of the five patients who had the index arthroplasty at The Hospital for Special Surgery had a urinary tract infection at the time of the index arthroplasty: one infection was due to *Pseudomonas aeruginosa* and the other, to *Escherichia coli*. Both of these patients had been treated prophylactically with oxacillin, and in both of them the subsequent late deep infection of the total knee arthroplasty was due to *Staphylococcus aureus*. Of the six knees that originally were treated at The Hospital for Special Surgery, the operative wound healed primarily in five. In one knee it healed uneventfully without antibiotic treatment despite slight serous drainage (which was not cultured). One of the five patients had bilateral arthroplasty in a room with horizontally directed laminar air flow, while the other four were operated on in a conventional operating room. The average number of personnel coming into the operating room was 7.2 (range, six to eight), which was the usual number for total knee arthroplasty at our hospital.

We were unable to identify any specific predisposing causes for the infections.

Particular attention was paid to the time of clinical onset of the infection and a specific bacteriological diagnosis was made for each patient.

The eleven postoperative infections in the entire series of ten patients developed both insidiously and acutely.

The average time between the index arthroplasty and the diagnosis of infection was sixteen months (range, one to forty-two months).

In three knees the infection was early (diagnosed within three months of the index arthroplasty), in six it was late (diagnosed after nine to forty-two months), and in two it was not clear when the infection occurred because the diagnosis was not made until biopsy and culture were done at revision, eleven and thirteen months after the index arthroplasty. In these two knees revision was performed because the arthroplasty was painful and had never functioned satisfactorily.

Of the eleven infections, three were blatantly systemic and were associated with obvious involvement of the knee, characterized by warmth, effusion, and tenderness. Five of the infections resulted in localized findings such as drainage, subcutaneous abscess, erythema, or rash and three, in a painful knee after arthroplasty.

The diagnosis was established preoperatively by culture of a specimen obtained on aspiration in seven knees and by culture of a specimen of the drainage in two. In the

other two knees the diagnosis was not made preoperatively because culture of the preoperative aspirate was negative in one and aspiration was not performed in the other. All patients who had a positive culture preoperatively had a positive culture of the operative specimen.

All causative pathogens were isolated from multiple specimens obtained at the time of surgical débridement or from multiple specimens obtained by preoperative aspiration of the joint. Nine of the eleven knees were infected by gram-positive organisms: *Staphylococcus aureus* in five, microaerophilic *Streptococcus* in one, and *Staphylococcus epidermidis* in three (in one of whom it was mixed with *Peptococcus* and alpha-*Streptococcus*). The two gram-negative infections occurred in the patient who had rheumatoid arthritis and involvement of first one and then the other total knee arthroplasty with *Pseudomonas aeruginosa*. In ten of the eleven knees, histopathological studies were performed when the prosthesis was removed. In eight knees the soft tissue contained acute and chronic inflammatory infiltrates, in one examination of a frozen section showed inflammation, and in the tenth knee there

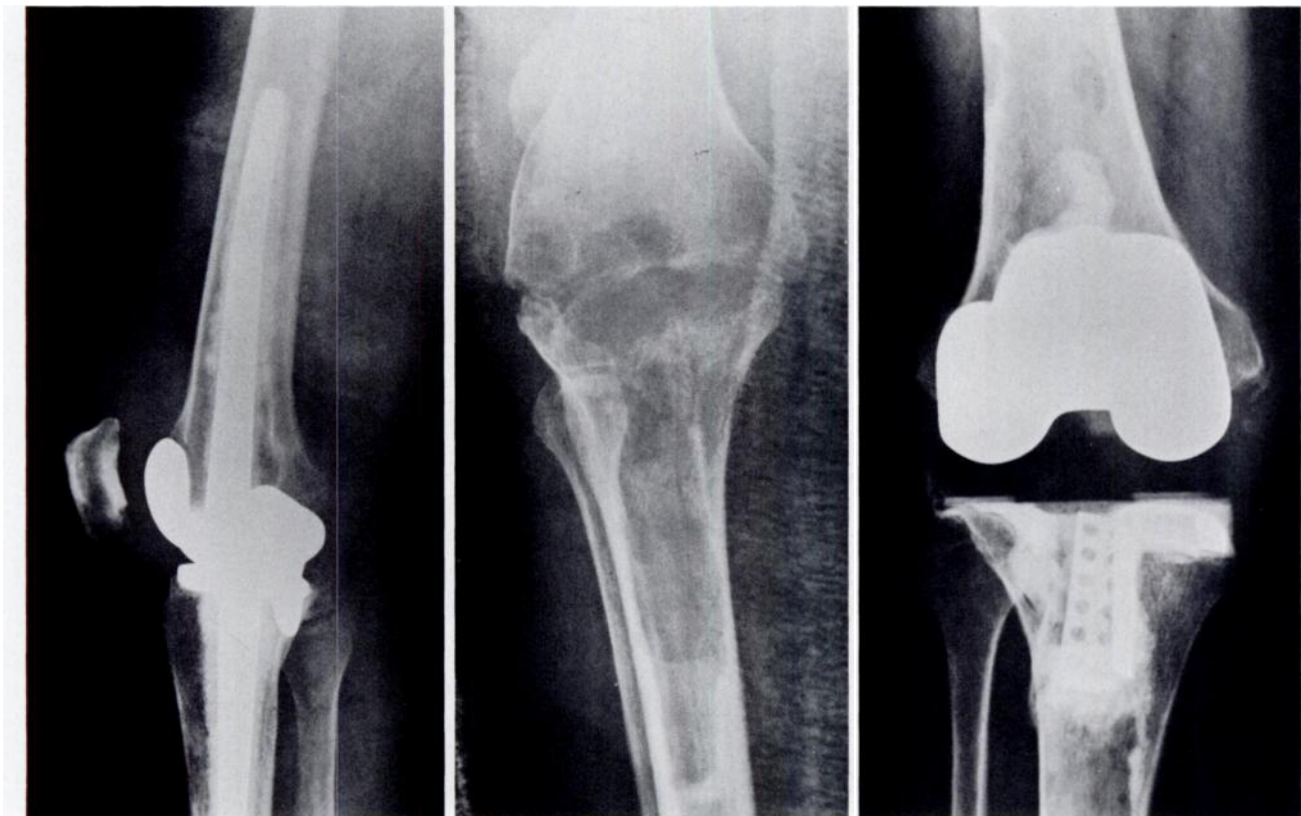


FIG. 1-A

FIG. 1-B

FIG. 1-C

Figs. 1-A, 1-B, and 1-C: Case 1. A sixty-four-year-old woman was seen three and one-half years after a Guepar arthroplasty.

Fig. 1-A: Radiograph made on admission, at which time the patient was in an extremely toxic state due to an acute infection of the knee and cellulitis which was spreading proximally along the lateral aspect of the thigh to the hip. The knee was aspirated and culture of the specimen grew *Staphylococcus aureus*. Despite intravenous administration of antibiotics the patient's condition became progressively worse, and the prosthesis had to be removed as an emergency procedure at night.

Fig. 1-B: Radiograph made after removal of the prosthesis, at which time the patient's condition improved remarkably and she was completely afebrile within a few days. However, at six weeks some inflammation and induration of the wound remained, even though culture of the aspirated material showed no growth. Antibiotic therapy was discontinued and a cylinder cast was applied.

Fig. 1-C: Radiograph made after reimplantation with a standard total condylar prosthesis was carried out four weeks later, at which time the wound had appeared benign. Although the original prosthesis had been hinged, the remaining soft-tissue sleeve was adequate to give good stability although titanium mesh was required to fill a defect in the tibial cortex. Rehabilitation was delayed by some superficial skin necrosis, but after a follow-up of forty-one months the patient had a range of knee flexion from zero to 85 degrees and an excellent clinical result.

was chronic inflammation and foci of necrosis. In the knee for which no histological studies were performed, the patient was moribund because of overwhelming sepsis; the prosthesis was removed as an emergency procedure at night, and no tissue specimens were obtained (Figs. 1-A, 1-B, and 1-C).

Surgical Management of Infection

Initially all patients were treated by removal of the prosthesis and cement. For this procedure a tourniquet was used, but the limb was not exsanguinated with an Esmarch wrap to minimize the risk of bacteremic seeding. The infected synovial membrane and pseudomembrane were

thoroughly debrided through the original incision. Cultures of multiple tissue samples were grown before any local or systemic antibiotics were used if the infecting organism or organisms had not been identified preoperatively. (Systemic antibiotics are now given after inflating the tourniquet if other total joint arthroplasties are at risk from hematogenous seeding.)

A sliding extraction hammer (Figs. 2-A and 2-B) was developed to remove the prosthesis. This device can be affixed to either the femoral or the tibial component so that the prosthesis can be removed by an axially directed force, thereby minimizing the risk of fracture of the remaining healthy bone. The patellar prosthesis was removed using

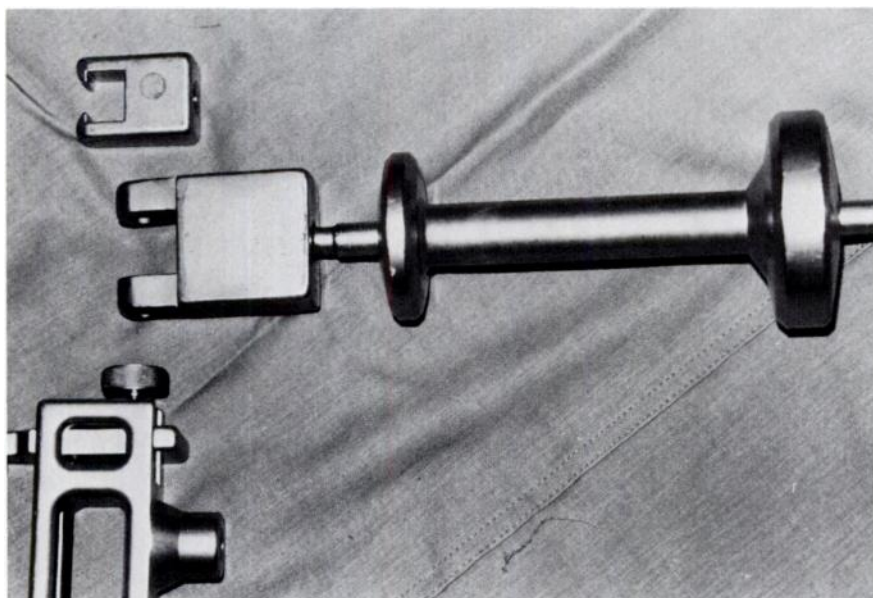


FIG. 2-A

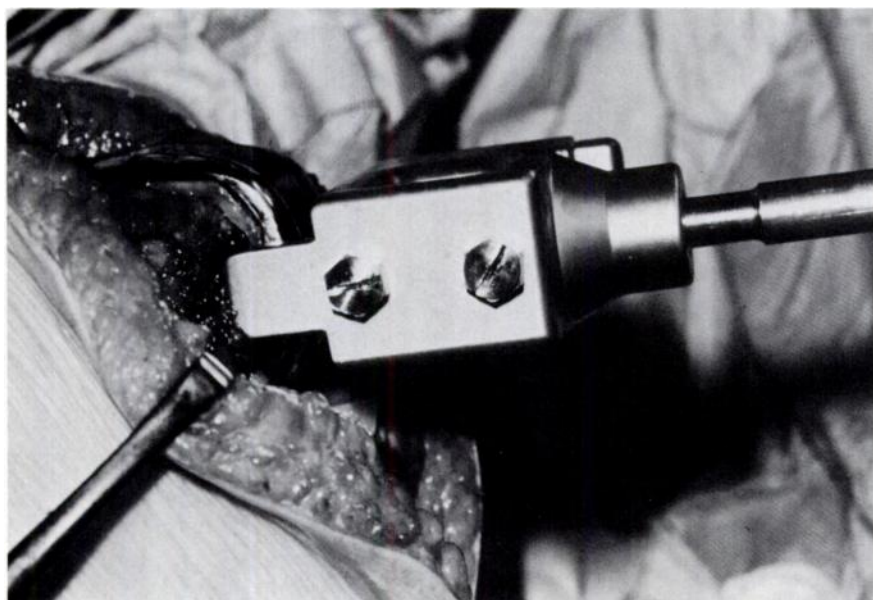


FIG. 2-B

Figs. 2-A and 2-B: Photographs of a sliding hammer with attachments for locking onto the components of a prosthesis. This device is very useful for the removal of implants when the knee is infected but the prosthesis is not mechanically loose.

an oscillating saw to cut the stem and remove the button. All remaining cement throughout the knee was removed with a high-speed, low-torque drill or, more painstakingly, with osteotomes. In knees in which there was any doubt that all of the cement had been removed, an intraoperative radiograph was made. The wound was copiously irrigated intraoperatively with several liters of normal saline to which appropriate antibiotics had been added. Large-bore suction drains were left in the wound for twenty-four to forty-eight hours. Irrigation inflow tubes were not used because of the risk of suprainfection. All wounds were closed primarily and a bulky dressing with plaster side-splints was applied to hold the knee in 5 to 10 degrees of flexion. Patients were allowed to walk using a walker, without weight-bearing on the affected limb, four to seven days after operation. The postoperative dressing was removed approximately one month after débridement for inspection of the wound and removal of the sutures. Twice-daily skin-cleaning was begun at that time, using soap and water, and paying special attention to the site of the incision. Alcohol was used to remove dry and flaking skin.

Medical Management of Infection

All patients were given parenteral antibiotics for at least six weeks after removal of the prosthesis. All antimicrobial regimens were designed on the basis of quantitative *in vitro* sensitivity studies, in which the minimum bactericidal concentrations of a variety of antibiotics were determined for each infecting organism. Once therapy had been instituted, its adequacy was confirmed by testing the serum bactericidal titer using a serial twofold tube-dilution method to determine the ability of increasingly diluted concentrations of the patient's serum to kill the infecting organism. The test was terminated at the highest dilution of serum causing 99 per cent destruction of a standard inoculum of the infecting organism. A serum bactericidal level of 1:8 or greater was set arbitrarily as the adequate antibiotic level to resolve the infection on the basis of the accepted effectiveness of similar titers in the treatment of bacterial endocarditis.

The initial antibiotic treatment was changed for six patients in order to obtain adequate serum levels. For example, a *Staphylococcus aureus* infection in one patient was treated serially with nafcillin, vancomycin, nafcillin, and finally ampicillin. Another *Staphylococcus aureus* infection was treated initially with cephalothin for five days, and then with nafcillin and gentamicin for six weeks. Drug synergy was exploited to treat relatively resistant organisms in five knees. The one mixed infection was treated with three drugs given simultaneously — vancomycin, cefazolin, and clindamycin — and the patient had a good result. After removal of the implant, one patient was treated with nafcillin for a *Staphylococcus aureus* infection of the knee and with a ten-day course of gentamicin for a concomitant urinary-tract infection.

In five patients (six knees), antibiotic therapy was

discontinued one to twenty-two days before reimplantation in order to observe the patient for signs of recurrence and so that the culture of the tissue specimen obtained at operation would not be influenced by antibiotic suppression. In the other five patients, antibiotic therapy was continued without a break from the time of removal of the implant until reimplantation six weeks later in order to shorten the duration of hospitalization.

At the time of reimplantation, prophylactic antibiotics were withheld until after operative specimens had been obtained for culture. Two patients whose original infection was treated with an unusual combination of drugs were treated with a more usual prophylactic antibiotic regimen (cephalothin or oxacillin) after reimplantation because it was assumed that the original infection had resolved and that only routine prophylaxis was required at revision. All antibiotics were discontinued three to eight days after reimplantation if the cultures of the specimens obtained at reoperation showed no growth.

There were no complications attributable to the antibiotic therapy. The patients were monitored for signs of leukopenia and renal dysfunction, and for auditory dysfunction when ototoxic drugs were used.

Reimplantation

All ten patients had removal of the old prosthesis and implantation of a new one during the same hospital stay. The time-interval between removal and reimplantation ranged from thirty-eight to eighty-two days, the mean interval being fifty-two days. Before reimplantation all knees were examined carefully to ensure that there was no clinical evidence of infection, and one to five specimens (average, 3.3) were cultured. In ten of the eleven knees, all cultures were negative and all antibiotics were discontinued three to eight days after operation. In the eleventh knee (of a patient with one infected arthroplasty), in which the initial infection had been due to *Staphylococcus epidermidis* mixed with alpha-Streptococcus and Peptostreptococcus, one of three specimens grew *Staphylococcus epidermidis* on culture, but only in the thioglycolate broth medium. Since this organism was considered a contaminant, all antibiotics were discontinued, as in the other patients, and wound-healing progressed uneventfully.

Gram stains of tissue-fluid specimens obtained during reimplantation in nine of the eleven knees showed no organisms, but histological sections from all eleven knees showed chronic granulation tissue in nine and both acute and chronic granulation tissue in two.

Exposure for reimplantation can be difficult, and care must be taken to avoid avulsion of the tibial tubercle when the quadriceps muscle is tight. A Coonse and Adams turndown of the quadriceps tendon can be used if avulsion of the patellar ligament appears likely, but postoperative immobilization will then be needed for three weeks. Partial or complete skeletization of the distal part of the femur or of the proximal part of the tibia may also be required. Turndown of the quadriceps tendon was not needed in this

TABLE I
CLINICAL FINDINGS AND OPERATIVE RESULTS

Case	Age at Index Arthroplasty (Yrs.)	Original Diagnosis	Interval between Index Arthroplasty and Diagnosis of Infection (Mos.)	Infecting Organism	Type of Prosthesis Used for Reimplantation	Length of Follow-up (Mos.)	Patellectomy	Extension Lag (Degrees)	Range of Motion (Degrees)	Femorotibial Angle (Degrees)	Results*
1	60	Rheumatoid arthritis	42	<i>S. aureus</i>	Total condylar	41	No	0	0-85	170	Excellent
2	74	Osteoarthritis	27	<i>S. aureus</i>	Total condylar II	30	Yes	5	0-120	168	Fair†
3†	67	Rheumatoid arthritis	3	<i>P. aeruginosa</i>	Total condylar II	20	No	0	0-100	177	Excellent
4†	67	Rheumatoid arthritis	10	<i>P. aeruginosa</i>	Posterior stabilized total condylar	12	No	0	0-95	170	Excellent
5	69	Osteoarthritis	11	<i>S. epidermidis</i>	Posterior stabilized total condylar	26	No button	0	0-90	175	Excellent
6	70	Osteoarthritis	1	Mixed	Custom-made total condylar III	36	Yes	30	0-120	180	Good
7	60	Osteoarthritis	13	<i>S. epidermidis</i>	Posterior stabilized total condylar	32	No	0	5-80	168	Fair
8	65	Osteoarthritis	10	<i>S. aureus</i>	Posterior stabilized total condylar	29	Yes	20	0-120	173	Good
9	60	Osteoarthritis	1	<i>S. aureus</i>	Duopatellar	44	Yes	0	0-90	180	Good
10	62	Rheumatoid arthritis	31	Microaerophilic Streptococcus	Custom-made total condylar III	72	No	0	0-90	180	Good
11	86	Osteoarthritis	18	<i>S. aureus</i>	Total condylar II	27	No	0	0-100	169	Excellent

* See text for definitions of knee rating system.

† Case 3 is the right knee and Case 4 is the left knee of the same patient.

‡ This rating was given before the development of a new infection.

series (although we have subsequently employed it), but some degree of skeletization was required in all patients.

Usually a non-constrained resurfacing prosthesis can be used for reimplantation, since a soft-tissue sleeve is preserved around the bones, but asymmetry of the sleeve may necessitate further release or division of the structures on one side. However, we do recommend the use of a posterior stabilizing prosthesis to provide the function of the posterior cruciate ligament. Occasionally the soft tissues are inadequate and medial-lateral restraint is required as well. In two knees a constrained total condylar-III prosthesis was used for this purpose. The decision as to whether to use such a prosthesis can be made at the time of operation.

Different types of total condylar prostheses were used in eight knees; a duopatellar prosthesis, in one; and a custom-made total condylar-III prosthesis, in two (Table I). Titanium mesh, perforated stainless steel, or Vitallium strips were used to reinforce the polymethylmethacrylate on the tibial side in eight patients. Strips of stainless-steel mesh were also used on the femoral side in one patient whose original Guepar arthroplasty was replaced with a custom-made total condylar-III prosthesis (Fig. 3).

Two patellae had been removed prior to reimplantation: one when the original prosthesis was removed and the other during the index arthroplasty. In two other knees patellectomy was performed at reimplantation to permit primary wound closure (Figs. 4-A through 4-E). In another patient the patella had not been resurfaced during the index duopatellar arthroplasty, but at reimplantation with a posterior stabilized total condylar prosthesis it was found

to be too thin and sclerotic to be resurfaced.

The perioperative complications after reimplantation in the ten patients did not compromise the results. All complications resolved with standard treatment. In three patients a deep-vein thrombosis was diagnosed on routine postoperative venograms (one of them accompanied by a positive lung scan), and although none of the patients had clinical symptoms they were treated with Coumadin (warfarin) anticoagulation therapy for two to three months. Three other patients had wound-healing problems: the first, delayed wound-healing with some necrosis of the skin margins; the second, a superficial wound hematoma which responded to local care; and the third, wound drainage from which rare *Staphylococcus epidermidis* was grown on culture. Because wound-healing progressed uneventfully in that patient, the culture was thought to reflect contamination of the skin surface. No skin grafts were required in any of the patients, but, as mentioned previously, patellectomy was necessary in two knees to allow primary skin closure.

The length of the hospital stay for the two stages of treatment of these ten patients ranged from seventy-two to 116 days (mean, eighty-five days).

All of the patients were seen at regular intervals after reimplantation and were examined by one or more of us, and the knees were rated by The Hospital for Special Surgery system³⁰ (85 to 100 points, excellent; 70 to 84, good; 60 to 70, fair; and less than 60, poor). At follow-up, radiographs were made with the patient standing and were examined for radiolucency or any signs of infection. Laboratory studies including a complete blood-cell count and erythrocyte sedimentation rate were also done.

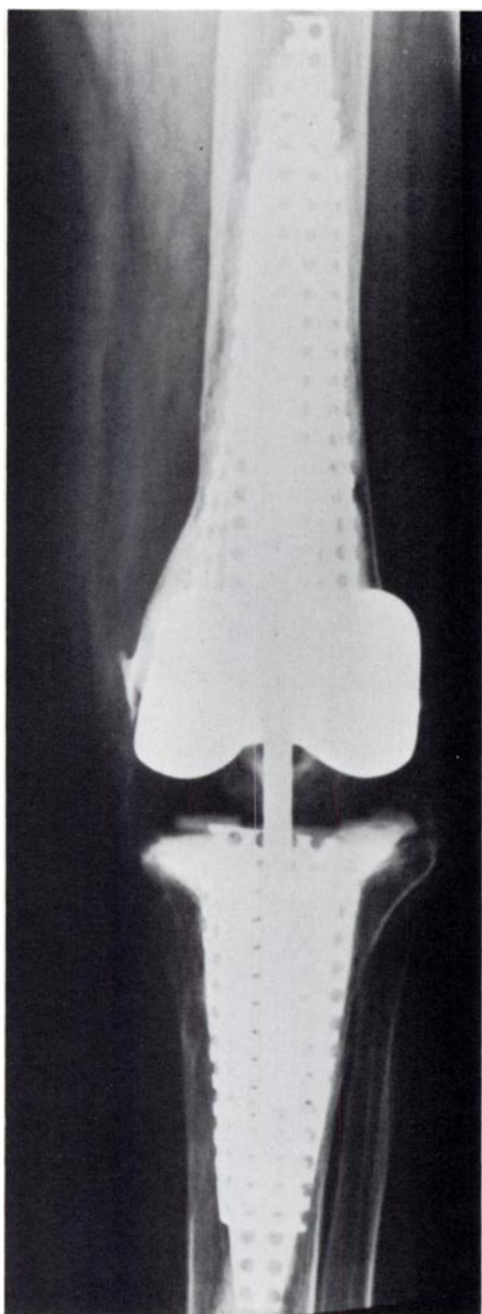


FIG. 3

Case 10. Radiograph made seventy-two months after reimplantation, showing the use of titanium mesh to reinforce the cement. The patient originally had had a Guepar prosthesis and only two hollow cones of femoral and tibial cortical bone remained after its removal.

Results

The eleven knees included in this study were followed for twelve to seventy-two months (average, thirty-four months). All but two of the knees were followed for two years or more, and the two that were followed for less than two years were in a woman who died of a myocardial infarct twelve months after reimplantation on the left side and twenty months after reimplantation on the right side. At the time of her death this patient had an excellent result in both knees.

Another patient had had a fair result except for an extension lag due to a patellectomy until thirty months after reimplantation, when the callus overlying a bunion on the side of the reimplanted prosthesis was trimmed and the bunion became infected. When the patient was first seen by us she had systemic sepsis, lymphangitic streaking from the foot to the knee, and pain in the knee. Culture of a specimen obtained on aspiration of the knee grew *Staphylococcus aureus* of a phage type that differed from that of the organism causing the original infection. The patient, who was eighty years old, refused more surgical treatment and was placed on suppressive antibiotic therapy. This was initially successful, but one year later she was readmitted with recurrent sepsis after she had stopped taking the prescribed antibiotics on her own volition. The knee was treated by incision and drainage, and antibiotic therapy was reinstituted. The infection then remained quiescent until she died of unrelated causes six months later.

Because we consider this to have been a new infection with a different organism, we recorded the result of the reimplantation as fair at thirty months, when the new infection developed.

Five knees were rated as excellent; four, good; and two, fair. One fair result was in a woman who was finally diagnosed as having a chronic pain syndrome. Re-exploration of the knee in this patient revealed no evidence of infection and when she was last seen her condition was slowly improving. The other fair result was in a woman in whom a patellectomy had been performed to enable wound closure. At last follow-up, this patient was old and feeble and she had a 5-degree extension lag. Although she used a walker she lived independently in a retirement home, despite a very limited ability to go outside the home. Of the four patients with a good result, two had an extension lag of 20 degrees or more before reimplantation that persisted after operation and the other two patients had minimum pain while walking, diminished tolerance for walking, and flexion limited to 90 degrees. In addition, these two patients had to use a banister for stair-climbing and used their hands to rise from a chair.

Considering all eleven knees, five were painless, two were mildly painful during walking, three were mildly painful only at rest, and one was moderately painful both at rest and while walking.

Five patients could walk and stand for an unlimited amount of time without difficulty, two could walk five to ten blocks and stand for more than thirty minutes without difficulty, and three could walk one to five blocks and stand for not more than fifteen to thirty minutes.

Of the ten patients, six (seven knees) required the support of a banister to climb stairs and four could ascend and descend without holding onto a banister. Six could rise from a sitting position without using their hands, and four had to use their hands to rise from a chair.

The amount of passive flexion in the eleven knees ranged from 80 to 120 degrees (average, 95 degrees). One

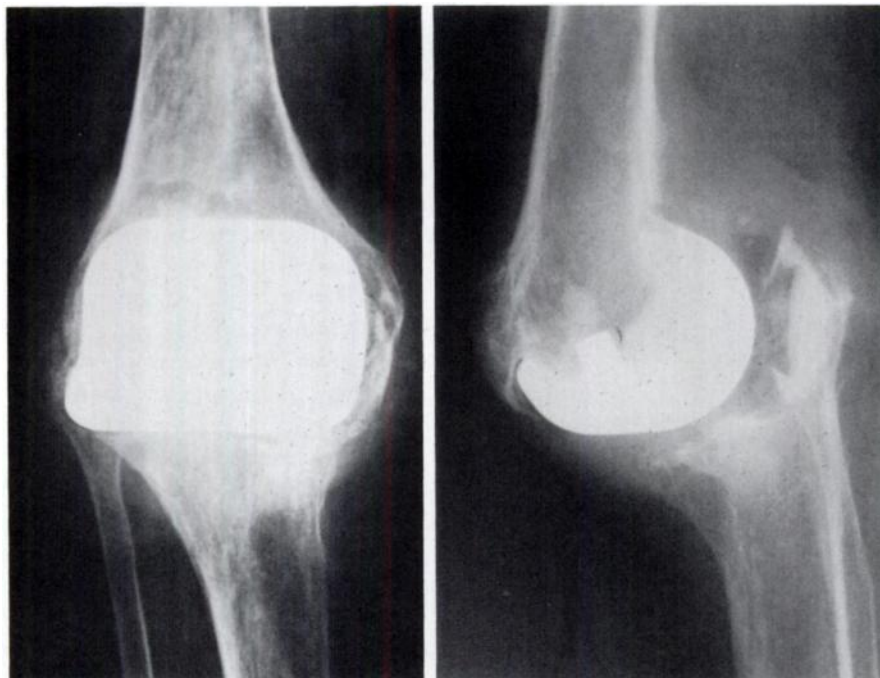


FIG. 4-A

FIG. 4-B

Figs. 4-A through 4-E: Case 9. A sixty-year-old woman had had a Freeman-Swanson arthroplasty for the treatment of osteoarthritis and a valgus deformity of the knee. Due to a previous open fracture she also had some valgus angulation of the ipsilateral tibia. After the arthroplasty she had much swelling and some skin necrosis.

Figs. 4-A and 4-B: Radiographs made eleven months after the initial arthroplasty, showing gross settling and a 90-degree rotation of the tibial component. The patella was adherent to the femur and the knee was ankylosed in extension.

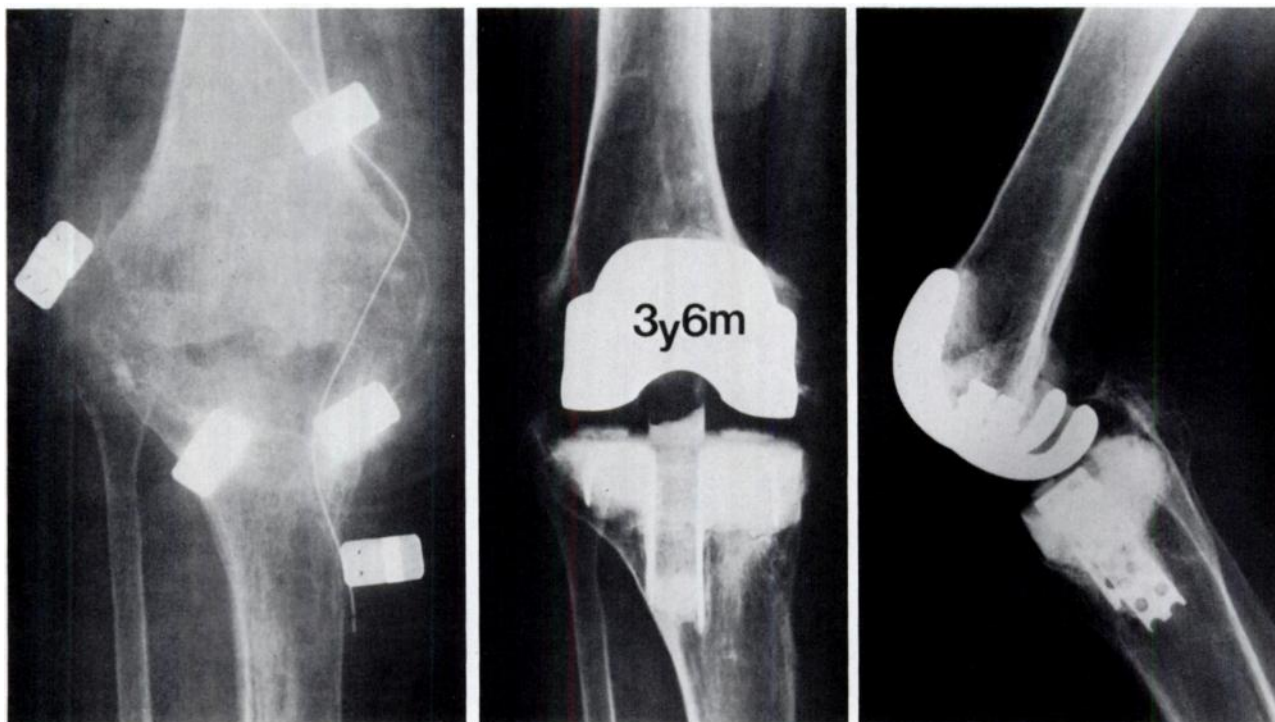


FIG. 4-C

FIG. 4-D

FIG. 4-E

Fig. 4-C: Radiograph made after the prosthesis was removed. Purulent fluid was found, and *Staphylococcus aureus* was grown on culture. Because of the large amount of scarring, it seemed doubtful that reimplantation would be successful, but it was undertaken six weeks after removal of the old prosthesis because the antibiotic therapy had been satisfactory and the wound appeared entirely benign. At operation the knee was mobilized relatively easily and an extra-small duopatellar prosthesis was used because the bones were very small.

Figs. 4-D and 4-E: Radiographs made at follow-up. A large defect in the anteromedial aspect of the tibia was reinforced with titanium wire mesh (Fig. 4-D) and the patella was excised in order to close the capsule (Fig. 4-E). After forty-four months the result was rated as good and the range of knee flexion was from zero to 90 degrees with no extension lag. The anteroposterior radiograph (Fig. 4-D) suggests a varus alignment because of the previous fracture of the tibia, but in fact the limb was in neutral alignment.

We do not now consider the method used in this patient to be satisfactory. We prefer to use a custom-made prosthesis designed to fill the large bone defect.

knee had a flexion contracture of 5 degrees and the others had a full range of passive extension. The quadriceps strength was excellent in eight knees to the extent that the examiner could not flex the knee against the patient's resistance. Three knees had an extension lag measuring 5, 20, and 30 degrees.

Considering all eleven knees, ten had no ligament instability and one had less than 5 degrees of medial or lateral angulation when the knee was stressed medially or laterally in full extension. No knee had a valgus or varus deformity of more than 5 degrees on clinical examination.

Five of the ten patients used a cane, but this seemed to be for the walking balance that many elderly patients require rather than for the relief of weight-bearing on a painful or weak knee.

A complete blood-cell count and erythrocyte sedimentation rate were obtained at the last follow-up visit for seven of the ten patients. All results were within normal limits. The hemoglobin levels ranged from eleven to 15.3 grams per 100 milliliters (average, 13.5); the white blood-cell counts, from 3800 to 12,000 (average, 6800); and the erythrocyte sedimentation rates (Westergren), from fifteen to thirty-three millimeters per hour (average, 28.6).

Radiographs made of the eleven knees at the last follow-up visit were examined to determine tibiofemoral alignment and to look for radiolucent lines. The alignment ranged from zero to 12 degrees of valgus angulation (average, 6 degrees of valgus angulation). The bone-cement interfaces of the patellar, femoral, and tibial components showed the following findings. Two knees had no radiolucent lines in relation to any component. One of six knees with a patellar button had a one-millimeter-wide radiolucent line extending along less than 10 per cent of the patellar bone-cement interface. Five of the eleven knees had no radiolucent line at the bone-cement interface of the femoral component, while six showed a radiolucent line extending along 33 to 100 per cent of the interface of the anterior flange, with one of these six also showing a line extending along 100 per cent of the posterior extension. Three of the eleven knees showed no radiolucent line at the bone-cement interface of the tibial component; three, a lucent line beneath the lateral plateau; and five, a line beneath both the medial and the lateral plateau. Five knees showed no radiolucent line at the bone-cement interface of the tibial stem and six had a line extending along 10 to 85 per cent of the contact area of the stem. During the twelve to seventy-two months that the eleven knees were followed, the radiolucencies did not progress, a finding consistent with those after revision of total knee arthroplasties in general³⁶. There was no radiographic evidence of loosening in any of the eleven knees.

Discussion

In the presence of an infected knee arthroplasty, there are several alternative methods of treatment: (1) antibiotic therapy alone; (2) incision, drainage, and débridement,

leaving the prosthetic components *in situ*, followed by long-term antibiotic suppression; (3) removal of the prosthesis, arthrodesis, and antibiotic therapy; and (4) reimplantation, as by the two-stage method described in this paper.

The results of antibiotic suppression alone have not been satisfactory in our experience, and we believe that arthrodesis should be a last resort. Incision and drainage may be appropriate for immediate postoperative infections and perhaps for acute-onset late infections. However, postoperative infection is not commonly seen while the patient is still hospitalized. We have treated only two such patients (neither in the present series) since 1971, and incision and drainage was unsuccessful in both. After two weeks of antibiotic therapy, purulent fluid was aspirated from both of these knees and the prostheses were removed. We concede that on occasion incision and drainage may suffice if it is done very early, but in general we prefer two-stage reimplantation. However, we must emphasize that for this procedure to be suitable the infecting organism must be identified and be susceptible to antibiotic therapy, and the patient must be robust enough to undergo two operative procedures and a long hospitalization.

The diagnosis of a deep infection can be elusive. A painful total knee arthroplasty without detectable mechanical cause should be considered to indicate infection until proved otherwise. If culture of the aspiration specimen does not yield the diagnosis, we recommend removing the prosthesis and awaiting cultures of the operative specimens. We have no experience in the use of radioisotopes to differentiate mechanical loosening from septic loosening in total knee replacement, although this has been used in the diagnosis of infected total hip arthroplasties.

Antibiotic management is critical. An infectious-disease consultant should orchestrate the selection, dosages, and synergistic combinations of drugs on the basis of serum bactericidal levels determined periodically during treatment. The antibiotic should be selected to maintain adequate bactericidal levels with the least toxicity. We believe that intravenous therapy is necessary, and therefore continued hospitalization is required. Antibiotic-impregnated cement was not used in any of our patients, and the antibiotics were discontinued permanently at the termination of parenteral therapy. Thus, the need for long-term suppressive therapy is avoided and oral antibiotics play no role in this method.

The surgical technique of removal of the prosthesis and implantation of a new one is difficult, and the procedure may not be suitable for surgeons without extensive experience or for every patient with a deep infection. The proper timing of reimplantation after antibiotic therapy must be based on the appearance of the wound, and when there is doubt about the appearance an aspiration should be done, antibiotics should be discontinued, and the wound should be observed for a few weeks before making a decision. Experience is required to make the correct judgment as to the timing of the reimplantation, but if the tissues

about the wound appear benign, with no edema or inflammation, and there is no pain, then reimplantation can proceed. When the knee is exposed, gram stains of the wound exudate are done and a tissue specimen is sent for examination of a frozen section. If any organisms are found or if the presence of polymorphonucleocytes suggests acute inflammation, the wound is closed without proceeding further. If the surgeon has any doubt about the condition of the tissues, it is better to discontinue the procedure and await further cultures.

ament is usually absent and correct spacing between the femur and the tibia during flexion and extension is difficult to obtain. Posterior subluxation in flexion may occur if a total condylar-type prosthesis is used and the fit in flexion is loose. The prosthesis can be used even when the previous device was hinged. It is desirable to avoid the use of an intramedullary stem for reimplantation, as such devices are difficult to remove should the infection recur. However, a total condylar-III prosthesis may sometimes be needed to obtain medial-lateral stability, and therefore one

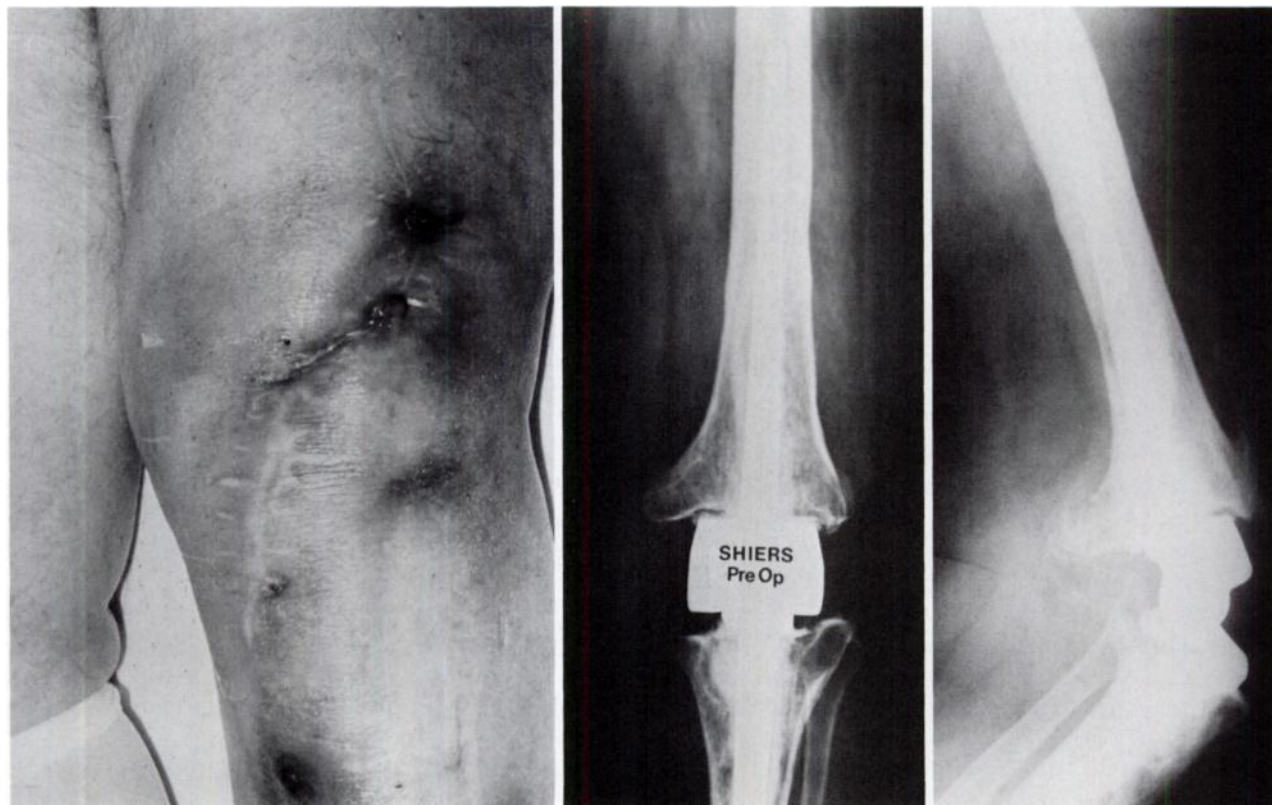


FIG. 5-A

FIG. 5-B

FIG. 5-C

Figs. 5-A through 5-E: Case 6. A seventy-one-year-old woman was seen one year after a Shiers arthroplasty.

Fig. 5-A: Photograph showing multiple draining sinuses. The patient had been told that she had a *Staphylococcus* infection immediately postoperatively, but the sinuses did not develop until three months before she was seen by us.

Figs. 5-B and 5-C: Radiographs made before removal of the prosthesis, which does not appear to be loose (Fig. 5-B). The patella was excised during the index arthroplasty (Fig. 5-C), and there was a 60-degree extension lag. Cultures at this time grew *Staphylococcus epidermidis*, *alpha-Streptococcus*, and *Peptostreptococcus*. After removal of the prosthesis, which was difficult, there was an excellent response to antibiotic therapy. At six weeks the wound appeared to be benign and a custom-made constrained total condylar-III prosthesis was implanted.

Skeletal traction is not required after removal of the implants from the knee. Instead, bone contact is preferable to reduce the amount of dead space, and provided reimplantation is not delayed for too long (two to three months) the joint space can be re-established without too much difficulty. Therefore, during the antibiotic phase of treatment the patient can walk without weight-bearing while wearing a bulky dressing. If no peripheral veins are still available for intravenous therapy, a Broviac catheter passed through the cephalic vein into the left auricle is a useful way to administer the antibiotics.

We recommend the posterior stabilized condylar prosthesis for reimplantation, as the posterior cruciate lig-

ament should be on hand. The final selection of the prosthesis to be used for reimplantation can be made during the operation.

While it is obvious that the results of reimplantation do not compare with those after a primary operation, all ten of our patients were satisfied, even the one with a painful knee. The major problem that we encountered was extensor weakness. Two patients had an extension lag of 20 degrees or more before the prosthesis was removed, and the problem persisted after reimplantation. Although they needed a walking aid, both of these patients were given a good knee rating (Figs. 5-A through 5-E). In two other patients a patellectomy was necessary in order to close the

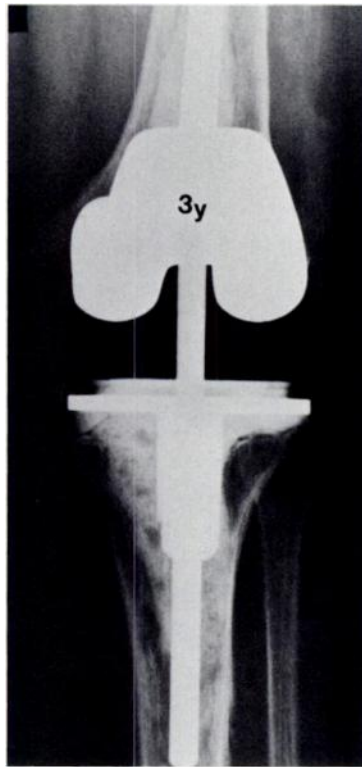


FIG. 5-D



FIG. 5-E

Fig. 5-D: Radiograph made three years after reimplantation, showing a partial radiolucency proximally, beneath the medial and lateral tibial plateaus.

Fig. 5-E: The wound appears to be entirely benign, without any evidence of swelling or induration. Because of the previous patellectomy, performed during the index arthroplasty, the patient continued to have quadriceps weakness and a 30-degree extension lag, and she had to use a walker for stability.

wound after reimplantation. One of these patients (Case 2) had an extension lag of 5 degrees and required a walking aid, and the other had a full range of extension. Except for

the problem of extensor weakness, the results in the patients in this series closely approximate those seen after primary arthroplasty.

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