Knee Arthrodesis

27

Gerhard Walter, Matthias Kemmerer, Oliver Seibert, and Rainer Hoffmann

Abstract

The vast percentage of arthrodesis patients today present with infectious complications after primary or revision total knee replacement. The patient must always be comprehensively informed of the advantages, disadvantages, and possible complications of a knee arthrodesis procedure, as well as possible treatment alternatives. There are medullary nails, compression nails, and modular distance arthrodesis systems available for arthrodesis of the knee. The first of these are introduced over the tip of the greater trochanter like a femoral nail and locked distally at the tibial isthmus. The latter must be inserted similarly to a joint endoprosthesis with a rigid module through an open approach. In cases where the bony defect is less than 3 cm, the compression nail should be used, and otherwise the knee arthrodesis module can be implemented. Both of these procedures are suitable for osteoporotic bone and for bulky soft tissues, and they enable early mobilization with immediate partial and in certain cases full weight bearing. The technique of both procedures is explained extensively. The results of a series of 106 knee arthrodesis is presented.

Keywords

Knee joint • Total endoprosthesis • Arthrodesis • Infection • Compression nail • Distance arthrodesis • Education • Amputation

27.1 History

The term "arthrodesis" comes from the Greek words "arthron," joint, and "desis," to attach, and in current terminology refers to an operative joint fusion. This procedure was introduced in 1887 by Zinsmeister with the article "On the Surgical Treatment of Paralytic Joints (Arthrodesis)" in the German Journal of Surgery [1]. The author published the results of his erstwhile chief in Vienna, Professor Albert, treating a paralytic "flail joint" with an operative knee fusion, first performed on July 10, 1878. He reported the subsequent ten procedures fusing either the knee or ankle joints, followed over several years and yielding favorable results in 9 cases. The procedure was carried out by resecting the affected joint surfaces and suturing the bones with silver wire. The etiology of the joint destruction was poliomyelitis

G. Walter, MD (✉) • M. Kemmerer, MD • O. Seibert, MD
Department for Septic Surgery, BG Trauma Clinic, Frankfurt am Main, Germany
e-mail: Gerhard.Walter@bgu-frankfurt.de

R. Hoffmann, MD, PhD
Department of Orthopedic and Trauma Surgery, BG Trauma Clinic, Frankfurt am Main, Germany

P.M. Rommens, M.H. Hessmann (eds.), *Intramedullary Nailing: A Comprehensive Guide*,
DOI 10.1007/978-1-4471-6612-2_27, © Springer-Verlag London 2015

in 8 cases, and post-infectious paresis after typhus and smallpox in two cases. The course of treatment averaged 6 weeks. The functional results were good, and the joints were stably fused. Prior to the procedures, the patients were completely non-ambulatory or dependent on complicated, expensive walking apparatuses unaffordable for a wide segment of the general population, and at the least were dependent on crutches.

In October 1927, W.R. Bristow presented an overview of the indications and technique of arthrodesis to the orthopedic section of the Royal Society of Medicine in London [2]. Pain and functional loss with or without deformity were indications for surgery.

Etiologies were:

- Arthritis from infectious, toxic, or metabolic causes,
- Trauma, foremost fractures with articular involvement,
- Paralysis, most commonly after poliomyelitis and more rarely after peripheral nerve injury.

He placed particular emphasis on the treatment of hip and knee joint tuberculosis, because he considered the results attained using conservative therapy with the agents available at that time unconvincing. He urged a more active approach, ensuring sufficient contact between the resected surfaces and then fixation with bone anchors.

In 1931, Professor Weil of Breslau published a chapter entitled, "Arthrodesis and Arthroereisis" in Results of Surgery and Orthopedics XXIV [3]. In this chapter, he offered a comprehensive history of joint fusion, and discussed the indications and technical details of the procedure for all potentially fusible joints. At the same time, the author examined practices of other European countries as well as the USA. In cases of paralysis, the recommendation was a marginal dissection of the articular cartilage, with stabilization exclusively using suture. Thus, naturally the dressing was of critical importance. Placement of a pelvic-leg cast was recommended for 8–12 weeks. The indication was paralysis of the knee muscles, particularly the extensors, and the indication was stronger for members of the "working class" than for sedentary workers. Rheumatoid arthritis, infectious arthritis, and post-traumatic arthritis as well as knee joint tuberculosis were also mentioned.

In March 1945, Küntscher and Maatz published "The technique of intramedullary nailing," in the Thieme publication from Leipzig, Germany. In this article, they gave an example of a knee joint arthrodesis, the x-ray of which looks astonishingly similar to our present-day results [4], (Fig. 27.1).

Fig. 27.1 Knee Arthrodesis with Kuentscher Nail 1945

In 1960, in Clinical Orthopedics and Related Research, John Charnley reported the results of 171 knee arthrodesis procedures performed by ten surgeons at his clinic, with a consolidation rate of 98.8 % [5]. The principle of compression arthrodesis was introduced, in which 45 kg of pressure was applied with an external fixator. Both operative time and rates of complication were minimal. The most common etiologies were post-tuberculosis joint destruction, primary gonarthrosis, and rheumatoid arthritis.

In the "Arthrodesis" chapter of the 1980 book "Arthritis of the Knee," Charnley reported that it was already difficult for young orthopedists to comprehend his enthusiasm regarding knee arthrodesis, which he had expressed 20 years previously [6]. In the meantime, knee arthroplasty had become so

well developed due to better functional results that joint fusion had been largely replaced as a primary treatment for gonarthrosis. It was only indicated in cases when the joint was so massively rigid that mobilization was no longer possible.

In an article published in the Journal of Bone and Joint Surgery (A) in 2004, Conway et al. summarized the still-current indications, results, and therapeutic alternatives for knee arthrodesis [7]. In industrialized countries, infectious disease has disappeared as a cause of knee destruction, as poliomyelitis is no longer a problem. In the meantime, knee arthroplasty as treatment of arthritis has taken off with an almost unanticipated boom. With the boom, the absolute number of postoperative complications increased, with the peri-prosthetic infection being the most feared. The incidence after primary operations was quoted 1–2 %, and after revision surgery, particularly septic revisions, it was markedly higher. Infection recurrence rates were reported as between 6 and 13 % by Wasielewski et al., and approximately 50 % by Hanssen [8, 9]. To date, these numbers have not markedly changed. Although revision implants and operative techniques have improved since then, the age and comorbidities of patients have continually increased, and the complication risks have risen accordingly. Knee arthrodesis is a withdrawal operation, allowing limb preservation with markedly reduced infection recurrence. Thus, we can thoroughly discuss the renaissance of this procedure with its long history and proven track record.

Our own investigations have shown the superiority of the intramedullary approach over that with an external fixator regarding permanent recovery from infection and good patient acceptance [10]. Currently, one survey recommends knee arthrodesis as the treatment of choice for recurrent infection after the first septic total knee arthroplasty revision [11].

27.2 Indications

Today, the spectrum of indications for knee arthrodesis has changed once again. The classic grounds for treatment including poliomyelitis, tuberculosis, and Charcot knee after tabes dorsalis are no longer present in the general population. The vast majority of cases of primary gonarthrosis as well as secondary joint destruction post-trauma or post-infection are treated with arthroplasty. The rate of postoperative early and late complications has barely changed in the past 10 years; instead it shows an upward trend as a result of the described demographic shift as well as an increase in the indications for surgery. The vast percentage of arthrodesis patients today present with infectious complications after primary or revision total knee replacement. In the authors' opinion, the following factors should support the implementation of arthrodesis:

- Chronic peri-prosthetic infection (present longer than 4 weeks),
- Infected soft tissue defect with fistula formation,
- Chronic osteitis of the distal femur or proximal tibia,
- Infection with multi-resistant pathogens,
- Destruction of the extensor mechanism,
- Compromised immunity of the patient,
- Advanced osteoporosis, in which long-term stable anchoring of a coupled revision total knee arthroplasty is improbable,
- Chronic pain syndrome.

Certain patients are so dissatisfied with their primary knee replacement that they refuse revision procedures and request a definitive treatment in the form of fusion at the initial interview.

Knee arthrodesis is also a consideration for the treatment of therapy-refractory chronic knee empyema and involvement of the neighboring bone in the absence of a knee prosthesis. This again should be considered in cases of multiple drug-resistant bacteria, mixed infections, and immunocompromised patients.

The risks of surgery, potential postoperative problems, and limitations in ambulation need to be carefully explained to the patient and his/her family members in multiple, consecutive interviews.

In specialized centers, malignant tumors of the distal femur and the proximal tibia are also added to the list of indications, when these cases cannot be treated with tumor endoprostheses. This chapter will not go any further into these details.

27.3 Contraindications

A knee fusion procedure is always an attempt to preserve the limb, for which revision, re-arthrodesis, and change of approach are also possible. However, knee fusion does not always promise good results. From our point of view, the major contraindications are:

- Progressively septic course with impending multi-organ system failure in cases of peri-prosthetic infection or knee joint empyema,
- General inoperability,
- Previously bedridden patients,
- Symptoms of spinal cord injury,
- Refractory peripheral arterial disease in stage IV.

Other potential contraindications are contralateral knee disarticulation or arthrodesis as well as severe arthritic deformities of the ipsilateral hip and/or ankle joints. Naturally, the functional results for patients with these comorbidities are massively reduced. In our opinion, in such cases it is particularly important to ascertain whether an arthrodesis might not be the best solution from a selection of suboptimal choices.

27.4 Patient Informed Consent

The patient must always be comprehensively informed of the advantages, disadvantages, and possible complications of a knee arthrodesis procedure, as well as possible treatment alternatives. We always involve the next of kin and caregivers in these conversations, and we never confine the discussions to the preoperative visit one day prior to surgery. Instead, it should be divided over several, sequential interviews. The informational discussions are carried out exclusively by colleagues who have already performed the procedure, or at least acted as an assistant. In addition, it is essential that the informing colleague has personal experience with the postoperative care of patients undergoing knee arthrodesis.

The patient must not be urged toward undergoing the procedure; instead, it is important to introduce treatment alternatives including complication rates and outcomes. The responsible physician must explain in detail his judgment regarding why knee fusion is the most suitable solution for the specific situation of the patient. If the patient is not yet convinced to have the procedure, he/she should be introduced to an external specialist experienced in knee joint revision surgery for a second opinion. If this colleague offers a different treatment option, then the patient can opt for either of the alternatives. For these extremely complex situations, there is still no commonly accepted treatment algorithm; thus, the learning curve is increasing for everyone involved with each additional case.

Once all parties have agreed to have the procedure, the following specifics should be collected, along with the customary clinical examinations:

- The type and dimensions of the scar: The patients have all undergone previous surgeries and have compromised soft tissues. Scars and fistulas must be described in the localized findings; preoperative photographic documentation is helpful.
- Peripheral pulses: An extensive clinical examination and documentation of the pulses of both legs is indispensable. If there are any abnormalities, Doppler and/or duplex sonography should be performed. If there is evidence of arterial occlusion, fine needle angiography or MR angiography should be added.
- Conventional x-rays of the femur and leg in two planes with ruler as gauge and inclusion of the adjacent joints. In cases of preexisting, clinically relevant axial deviation, additional full-length lower extremity x-rays are recommended, also with a ruler. More extensive imaging procedures (CT, MRI) should be reserved for specific situations.
- Knee arthrodesis is generally an elective procedure, and thus, significant comorbidities should be clarified and optimized in an interdisciplinary manner. The preparation of blood products is generally unnecessary in cases of external fixator use, and in cases of the intramedullary approach, 2 units of packed red blood cells should be made available.

27.4.1 Advantages of Knee Arthrodesis

Knee arthrodesis offers functionally worse outcomes than a well-fixed, infection-free knee joint endoprosthesis including the distal femur or proximal tibia replacements. There is no doubt of this, which is why it is particularly important to carry out thorough informational interviews as previously discussed. However, knee fusion offers significant advantages compared to an unstable or infected knee endoprosthesis or an amputation. Conway evaluated knee arthrodesis with 70 points on the knee society score, while amputation or failed revision reached less than 50 points. When arthrodesis is performed correctly, the risk of re-infection is significantly lower compared to revision arthroplasty [9, 12, 13]. If a knee arthrodesis leads to bony consolidation, complete hardware removal of external fixator and compression nail is possible. Thus, the risks for revision surgeries or implant-associated infections are eliminated. In our experience, the reinfection rate after the use of a distance arthrodesis (see below) is less than that after a septic prosthetic revision; however, the knee joint arthrodesis module (KAM) remains for the patient's lifetime.

After knee disarticulation, many patients remain ineligible for new prosthesis and non-ambulatory, and thus, disabled. Pring et al. reported that only 30 % of amputees were ambulatory [14]. In addition, amputees consume some 25 % more energy compared to knee arthrodesis patients [15]. The proportion of patients with persistent pain in the knee is 10 % after the first knee endoprosthesis and increases with each revision. Husted et al. reported on 24 patients suffering peri-prosthetic infections after primary knee endoprosthesis [16]. A two stage prosthetic revision was undergone in 17 cases. The infection was eliminated in 15 cases, but 8 suffered persistent pain. After placement of a knee arthrodesis, however, improvement of pain symptoms can be achieved in over 90 % of patients [10].

Generally, functional outcome is improved in relation to younger age and better mobility and thus better bone quality of the patient at the time of arthrodesis.

27.4.2 Disadvantages of Knee Arthrodesis

Functionally, the principal problem with the permanent joint loss is that of sitting in spaces with decreased legroom (airplanes, theater, cinema). The use of small cars can be problematic, as can climbing ladders. Half of patients will require the permanent use of crutches. Walking distance can remain limited. Limb shortening of approximately 1 cm is the goal

of surgery; however the leg length difference can turn out to be longer. Compared to healthy persons, the energy cost of walking is increased by approximately 25 %.

Over the further clinical course, increased load of the ipsilateral hip and ankle joints can be assumed. Thus, pre-existing arthritis can emerge or worsen. The loss of function is permanent. Correction of arthrodesis with endoprosthesis placement after the fact is prone to complications and is rarely performed [17].

27.4.3 Alternate Approaches

Alternative treatment options to arthrodesis yield significantly worse functional outcomes. With knee resection arthroplasty, the joint or the endoprosthesis are removed without replacement, and the limb is stabilized with a supporting orthosis. This spares the patient further operative interventions, but the limb remains unstable and non-weight bearing. Another alternative is the permanent placement of a cement space holder, although in our experience this leads frequently to complications. The joint develops a flexion contracture or the space holder can displace and lead to mechanical irritation. For this reason we no longer offer this procedure.

Knee disarticulation or distal femur amputation remain as radical solutions. However, few patients will be eligible for prosthetics, and thus, will be non-ambulatory [13]. Femoral amputations have a 30 day mortality of up to 22 % and should be performed in older patients only in desperate situations, e.g. in cases of uncontrolled, progressive infections [18]. For active, mobile patients, we see an indication for this only when there is loss of sensation in the leg or when a serious, surgically untreatable circulation problem is present.

Currently, as a result of improved implants and operative techniques, alternative therapies are seldom called for in the treatment of "complicated peri-prosthetic infection of the knee."

27.5 Operative Method

In this section we introduce the alternative operative methods for knee arthrodesis. The surgeon should be familiar with all of these procedures, and should discuss them, including the corresponding advantages and disadvantages, during the information interviews conducted with the patients and their relatives.

27.5.1 External Fixator

The external fixator is the oldest known arthrodesis procedure and was mentioned in its original form already by Hippocrates in 400 B.C. It remains an installment of septic surgery and is the workhorse in the treatment of complicated knee infections with or without implants. It is a soft-tissue sparing implant, that can be applied in a minimally-invasive manner and allows re-reduction and/or repositioning at any time. Depending on the type and extent of bony defect present, it can be mounted with either a bi- or tri-planar joint bridge. The fixator can be dynamized without anesthesia, and hardware removal can be performed in an ambulatory setting. If the underlying biomechanical principles are respected during implantation, the placement is simple and uncomplicated, and proceeds remote from the infection. This implant is unrivaled in its reasonable price.

27.5.1.1 Indications

In our opinion, the external fixator is indicated for knee arthrodesis when there is relatively little bony loss, the bone quality will allow stable anchoring of a pin for 12 weeks, and the patient is capable of active participation in care. Problems can be expected when these conditions are not fulfilled, for example: If there is high-grade osteoporosis, if the patient is not capable of observing complications arising from a placed fixator, or if direct contact of the resected surfaces of the femur and tibia cannot be established because of extensive bony loss.

27.5.1.2 Outcome

The consolidation rate of knee arthrodesis using an external fixator is high with active, mobile patients with good bone quality. In such cases, the healing rate is up to 90 %. However, it is for these patients that an external fixator is a great imposition, since the fixator impedes the patients in many areas of daily life, requires daily care, and is perceived as unpleasant. In cases of older, less mobile patients with poorer bone quality, the treatment results are unsatisfactory. The consolidation rate is under 50 %, pin infections and/or loosening are more common, and the daily care by external personnel is difficult to organize.

Thus, we use the external fixator for a limited number of arthrodeses, and instead use it as a temporary immobilization in cases of pronounced peri-prosthetic infections prior to a later procedure with an intramedullary device.

27.5.2 Plate Arthrodesis

27.5.2.1 Indications

Knee arthrodesis with compression plates is possible when there is relatively little bone loss, when the infection has been subdued, and when a sufficient soft tissue mantle is present.

The major disadvantage of plate arthrodesis is that it involves an extensive, extraosseous implant. Closing the soft

tissues, which are often previously compromised, can offer a considerable challenge. The typical double plate arthrodesis with insertion of the implants medially and laterally often requires an additional incision, which leads to further damage of the skin and subcutaneous tissues. For these reasons, Jones et al. recommend this approach only when other methods have previously failed [19].

27.5.2.2 Outcome

In 1987, Munzinger et al. published a series of 34 patients who had undergone AO compression plate arthrodesis and showed a stable consolidation after an average 6 months [20]. Nichols et al. treated 11 patients with double plate fixation and found bony consolidation in all cases after an average 5.6 months. They reported two complications requiring revision: a femoral fracture and a recurrence of infection [21].

All authors carried out the arthrodesis first after the initial infection had been subdued.

27.5.3 Intramedullary Approach

For this approach there are medullary nails, compression nails, and modular distance arthrodesis systems. The first of these are introduced over the tip of the greater trochanter like a femoral nail and locked distally at the tibial isthmus. The latter must be inserted similarly to a joint endoprosthesis with a rigid module through an open approach. For both of these approaches there are various implants available, which are selected for individual cases based on the personal experience of the operating surgeon.

Intramedullary approaches were already recommended for knee arthrodesis in the mid-1940s [22]. Despite good results, however, the approach did not become well established. The implantation of a Kuentscher nail was repeatedly advocated in the 1980s, and was used also in our clinic. The main concern at that time was the spread of infection into the medullary canals of the femur and tibia. Implant failures were observed, and the removal in cases of material failure or recurrent infection could be performed only with difficulty. Thus, this procedure was also not in widespread use.

Many of these issues were resolved with the introduction of a titanium compression nail with customized design. The T2 IM Nailing System (Manufacturer Stryker, Freiburg, Switzerland) is constructed of an anodized TI6AL4V alloy with markedly improved biomechanical properties. It can be inserted in a minimally invasive manner without using the previous incisions, and it enables active compression between the femur and tibia. The knee arthrodesis module (KAM, Manufacturer Brehm, Weisendorf, Germany) is used for defect areas 3 cm and larger, and can be used for defects in the distal femur to the proximal tibia. Compared to the T2 nail, the KAM does require re-opening the old approach, and the implant remains permanently in situ.

27.5.3.1 Indications

The overall operative status of the patient must be considered: this procedure lasts between 90 and 120 min and results in blood loss between 500 and 1,500 mL (personal observation). In cases where the bony defect is less than 3 cm, the T2 compression nail should be used, and otherwise the knee arthrodesis module can be implemented. Both of these procedures are suitable for osteoporotic bone and for bulky soft tissues, and they enable early mobilization with immediate partial and in certain cases full weight bearing.

Intramedullary knee arthrodesis cannot be implanted in cases of florid osteomyelitis and lingering deep tissue infections. An ipsilateral total hip arthroplasty precludes the use of a T2 nail. In these patients, a KAM must be planned. The already noted general contraindications hold such as severe, therapy-resistant neurovascular lesions of the leg and foot.

27.5.3.2 Outcome

Intramedullary procedures are the current preferred method for knee arthrodesis. These methods are convincing because of their minimal invasiveness and because they are less stressful for patients. This is because of the simple care and good comfort, a high fusion rate, and the possibility of early mobilization with partial weight bearing. Because laboratory and microbiological control of infection is required, the procedure must be performed in two stages.

27.6 Operative Technique

27.6.1 Arthrodesis with IM Compression Nail

The T2 IM compression nail for knee arthrodesis is manufactured by Stryker from a type 2 anodized titanium alloy (Ti6Al4V), and is 240–420 mm long with diameters of 11.5 and 13 mm available.

27.6.1.1 Planning

Generally, for this procedure, full-length x-rays of the femur and leg with ruler are sufficient. Full leg CT determining the distance between the trochanteric tip and the distal femoral condyle on one side and between the tibial plateau and the ankle joint line can also be performed, as well as measurement of the femoral and tibial medullary canal diameters.

In our experience, blood loss from the required reaming of the femoral and tibial canals is generally between 500 and 1,500 mL. Particularly older patients with multiple illnesses may require transfusion. This should be taken into account preoperatively.

27.6.1.2 Procedure

The procedure is performed with the patient in the supine position and with the proximal femur set under an image intensifier in two planes beneath the sterile drapes.

The incision should be placed over the greater trochanter, approximately 5 cm towards proximal. The gluteal fascia is split, and blunt dissection of the gluteus medius muscle fibers is performed. The tip of the trochanter is exposed circularly from superior. The entry point for the arthrodesis nail is exactly in the projection of the femoral shaft axis in both anteroposterior and axial directions. We recommend the use of a curved, cannulated awl with a bayonet handle that allows a minimally invasive approach even with large amounts of soft tissues. The positioning is controlled in two planes with the image intensifyer. After opening of the cortex, a 150 cm long guide wire is fed into the femoral canal, again under imaging guidance. If introduction of the guide wire into the tibia is difficult, this can be directed manually through a 3–4 cm long incision through the previous scar. If the knee needs to be opened for spacer or chain removal, the guide wire can be introduced in a retrograde fashion from the condyles to the greater trochanter under image intensification, and then inserted in an anterograde fashion proximally into the tibia.

The tip of the guide wire should then be centrally placed above the malleolar fork. The femoral and tibial canals are then enlarged by reaming multiple times, beginning with the smallest reamer of 8.5 mm and increasing in 0.5 mm increments. For the primary implantation, a T2 arthrodesis nail with an 11.5 mm diameter is chosen. The tibial canal is reamed to a head size of 12.5 mm, and the femoral canal to 13.5 mm. Implant length is determined by measuring the remainder of the guide wire and comparing with the preoperative plan. The most suitable implant is chosen from the available lengths, and hammered in over the guide wire under constant imaging control. The tip of the nail should lie beneath the tibial isthmus. Deviation of the femur and tibia from hammering should be avoided and/or corrected. Depth of the hammering proximally should also be observed. Distal locking is then performed with a free-hand technique from medial. Afterwards, the nail is carefully back-hammered. Particular care must be paid to osteoporotic bone, because a medial femoral neck fracture can occur even without much applied force. Proximal locking is then performed with the targeting device. Here a compression screw can be inserted, which can push the cross bolt through the compression slot up to 10 mm distally and thus also approximate the tibia by this distance. A second static locking screw may be optionally inserted. Finally, the screw cap is applied, in lengths of 5–20 mm.

The accumulated bone debris of the tibia and femur collected during reaming are pressed within the bony defect of the former implant on the femoral condyles and tibial head. Thus, additional cancellous bone graft is required only in exceptional cases (Fig. 27.2a–k).

27.6.1.3 Complications

In cases where the entry portal is false, the nail has too large a diameter, or with too much hammering force, a medial femoral neck fracture or a femoral or tibial shaft rupture can occur. With too little stability after nailing, with a gap or bony defect at the level of arthrodesis, consolidation can fail to occur.

Malrotation should be avoided through repeated intraoperative clinical and radiological controls. Due to closing of the bony defect, leg shortening should always be anticipated as a result of resection arthroplasty.

27.6.1.4 Post-operative Care

If fractures and fissures are radiologically excluded, early mobilization can begin with 20 kg partial loading. After 6 weeks, increasing load can be allowed.

If there was no evidence of persistent infection preoperatively, antibiotic prophylaxis can be performed over 24 h, specifically targeted at the last documented pathogen. If the preoperative infection appeared silent on clinical and laboratory examination, but intraoperative cultures showed growth, antibiotic treatment is given for 6 weeks.

27.6.2 Distance Arthrodesis

Distance arthrodesis, or endoprosthesis with rigid joint module, allows stabilization of longer bony defects after complicated joint infections with extensive limb length preservation (Fig. 27.3a–i).

There are cement-free anchoring systems available in two lengths (140 and 200 mm) for straight and three lengths (200, 260 and 320 mm) for curved, anatomically-adapted geometry. The shafts are vertically ribbed to prevent rotation and telescoping. The coupling occurs over a module available in neutral position or in 6° of valgus. We've had good experience with the shafts even in cases of significantly damaged, high-grade osteoporotic bone (see below). In principle, the use of cemented shafts is also possible. In cases of damaged bone, however, we consider this unnecessary, since even elderly and marked osteoporotic bone shows stable bony ingrowth as a rule. An additional cement block for stabilization is contraindicated, and additional cancellous bone graft for defect filling is not required. The procedure should be suitable for stabilization of unstable arthrodesis after external fixator or T2 IM compression nail use (Fig. 27.4a–j).

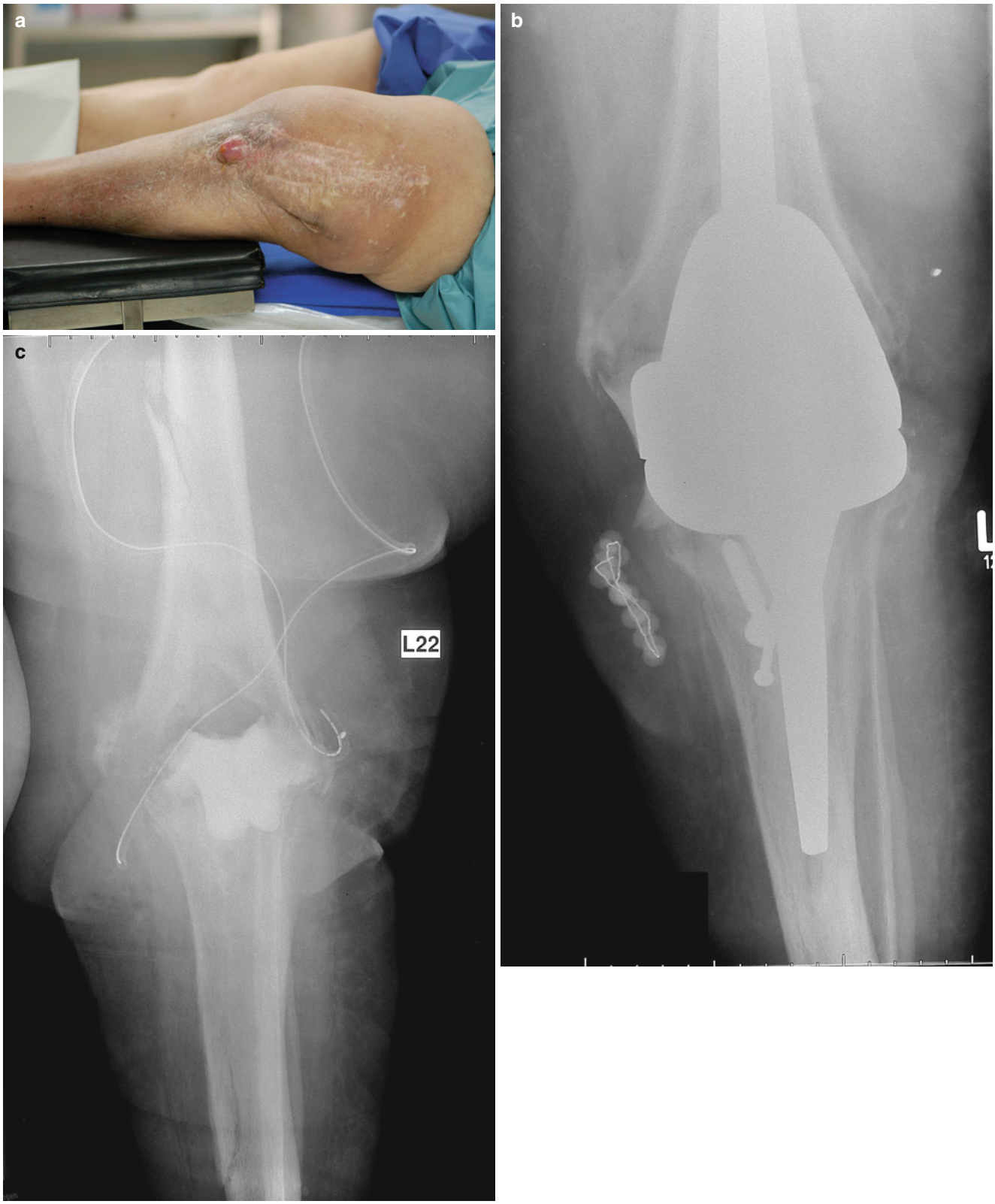


Fig. 27.2 Sixty-seven year old man; morbid obesity, BMI > 40 kg/m^2; cardiac and renal insufficiency, atrial fibrillation, anti-thrombotic drugs. Knee prosthesis 2002, aseptic revision 2004, infection 2006 with fistula formation, prosthetic loosening. (**a**) Clinical picture. (**b**) Radiographic picture. (**c**, **d**) Knee prosthesis explantation, canal revision of the femur and tibia with sequestrectomy, spacer implantation. On the femur and tibia, cortical perforations are visible. (**e**–**g**) Condition after T2 compression nail arthrodesis, post-operative day 2. (**h**, **i**) Radiograph 18 months post-operatively. (**j**, **k**) Clinical findings 18 months post-operatively

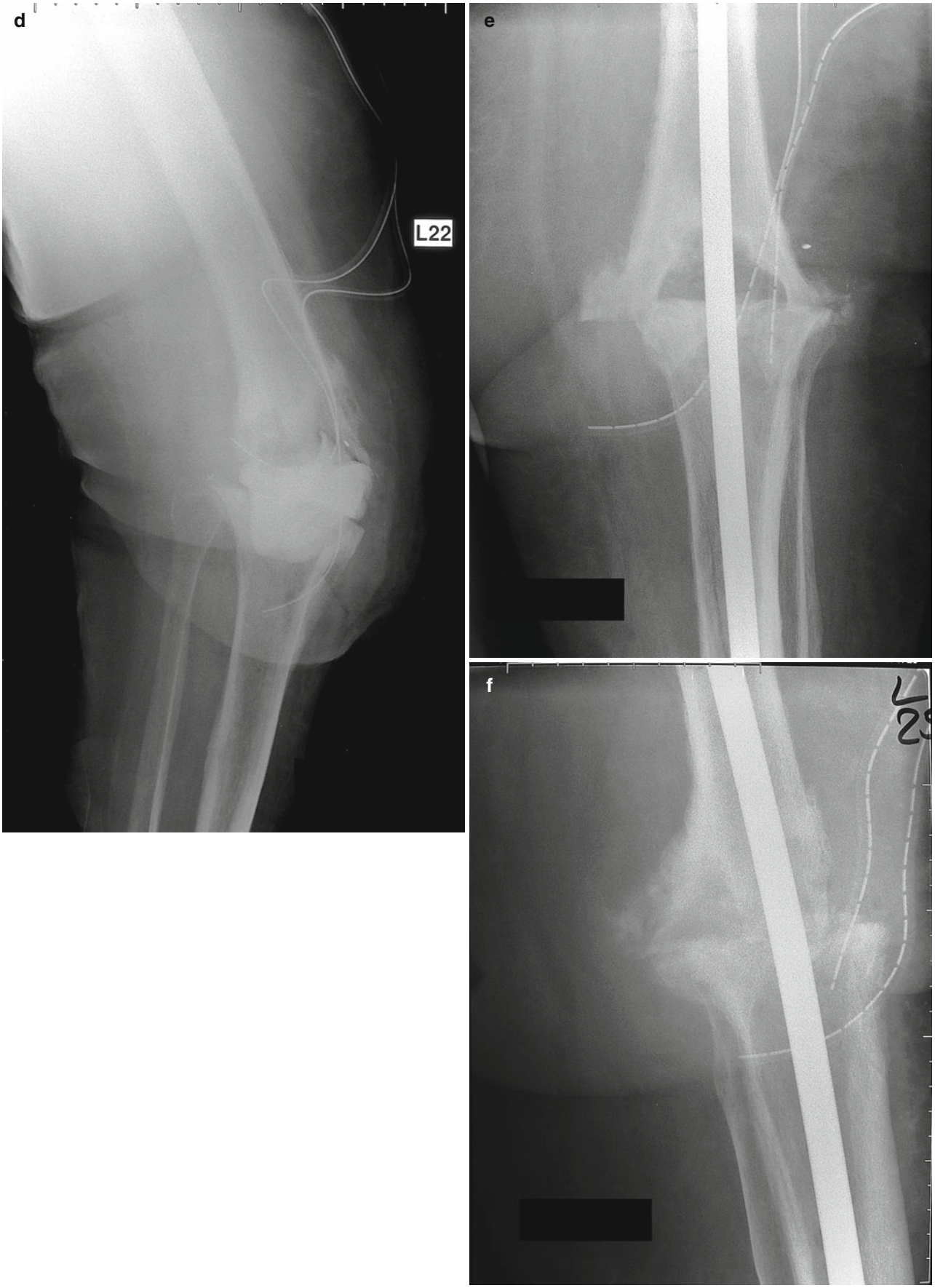


Fig. 27.2 (continued)

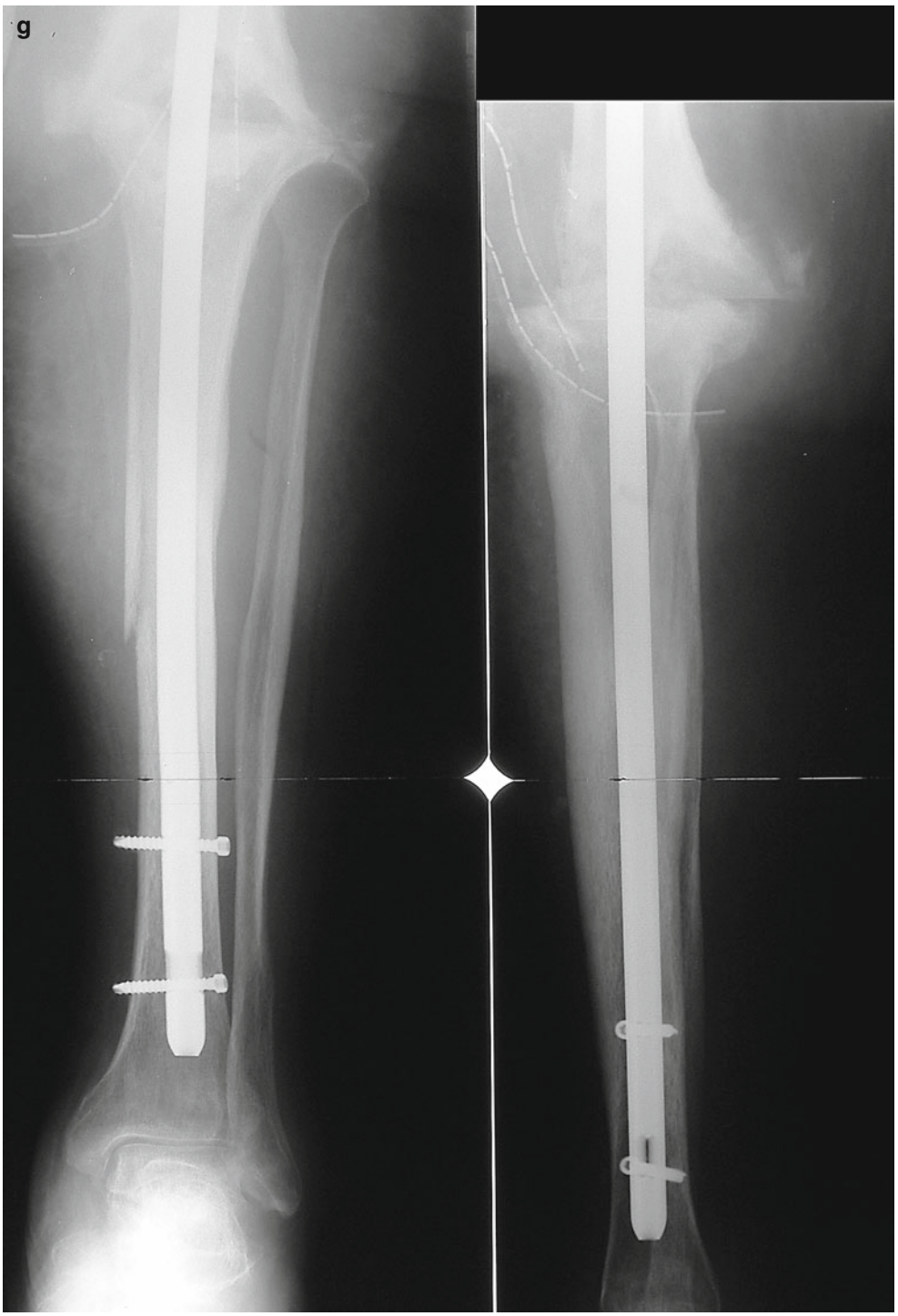


Fig. 27.2 (continued)

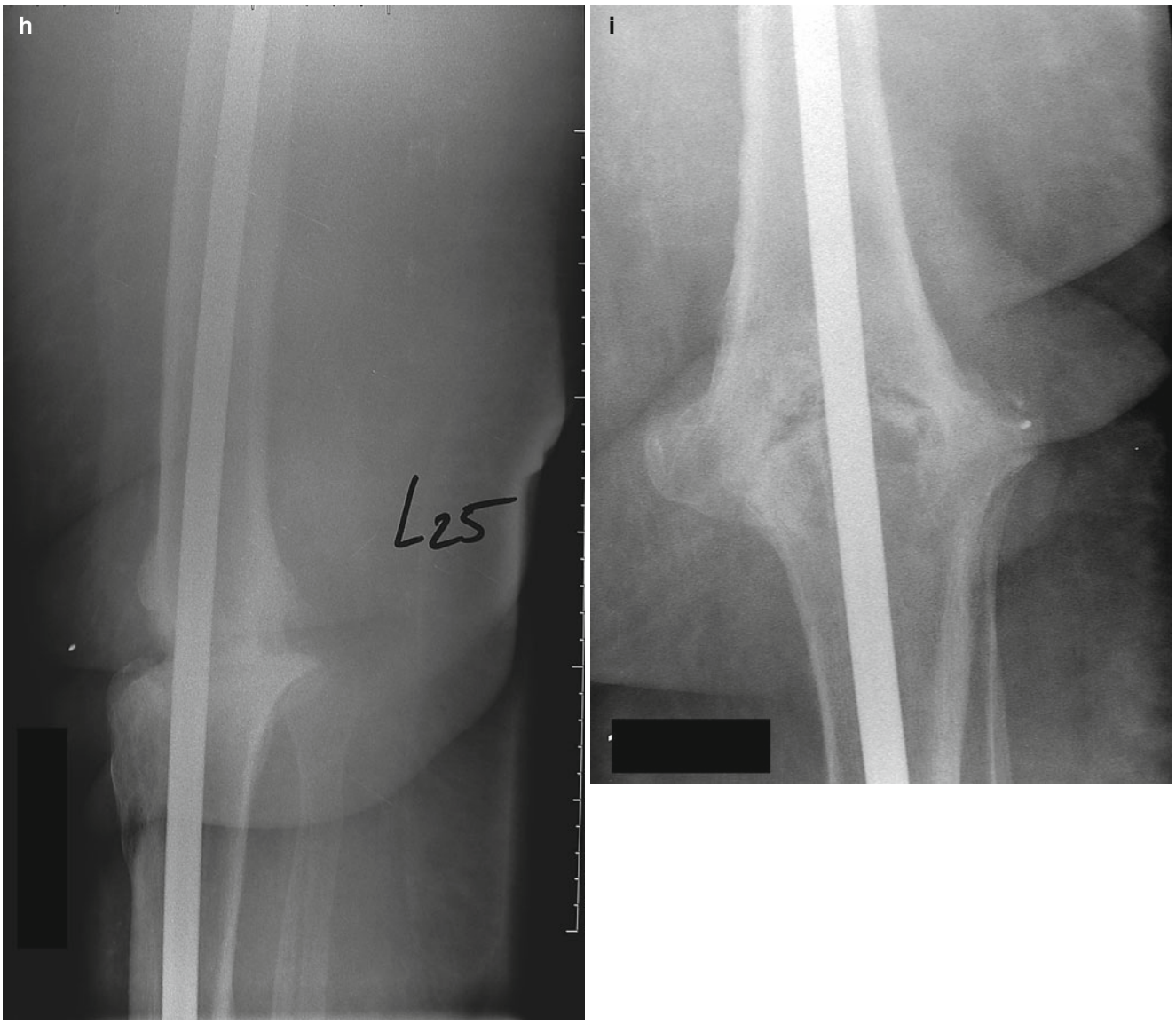


Fig. 27.2 (continued)

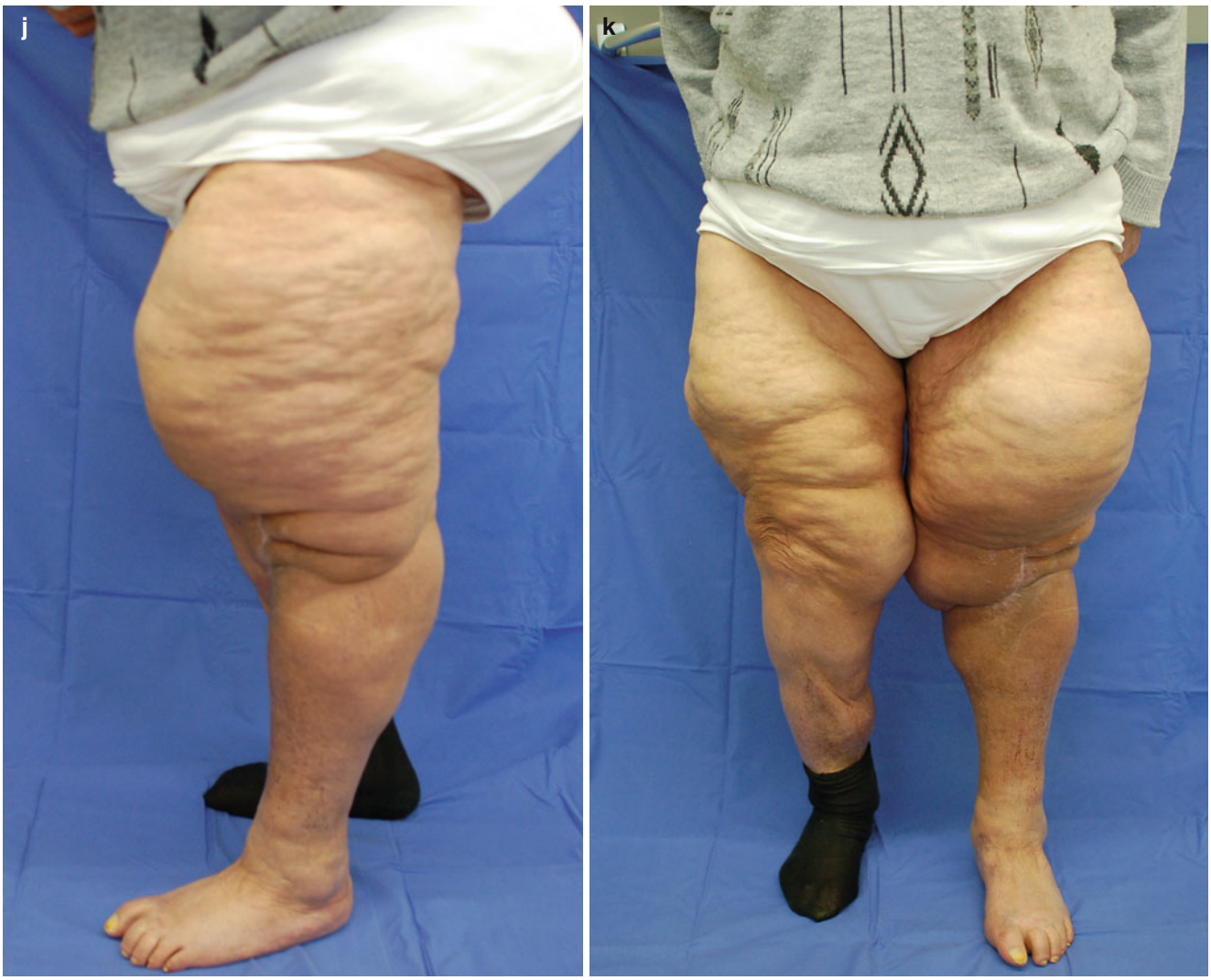
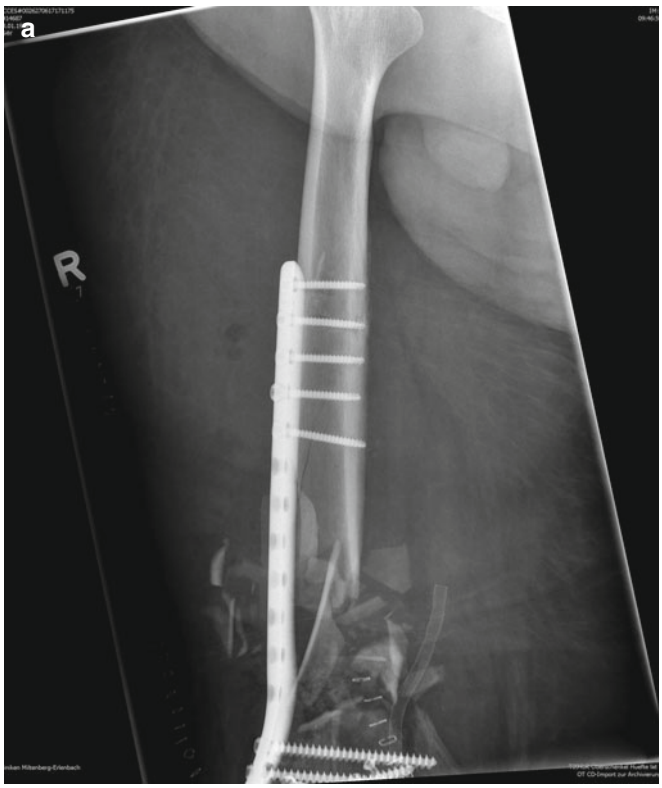
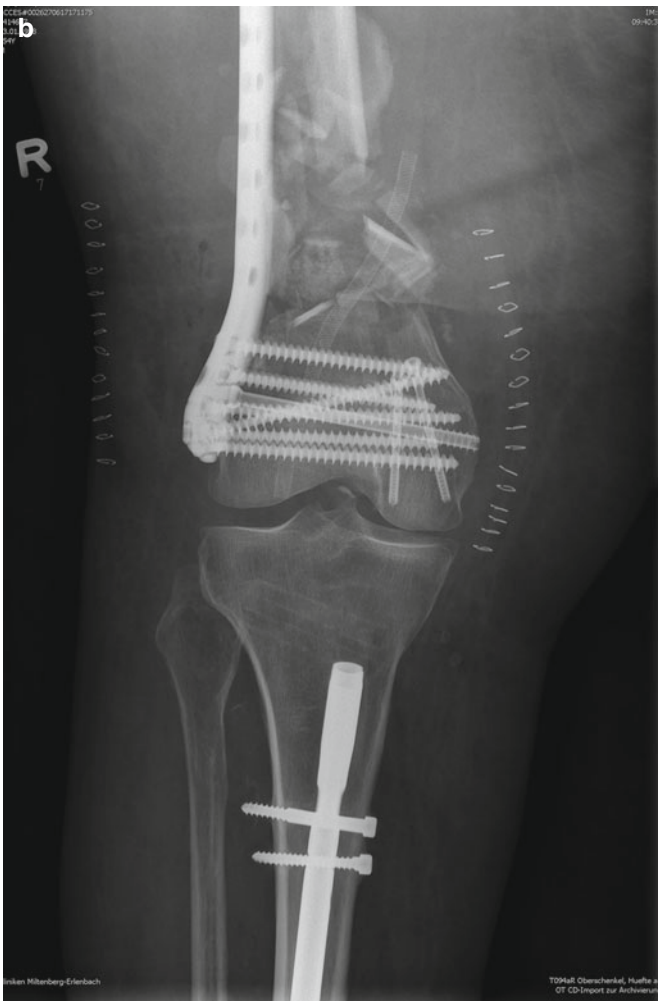
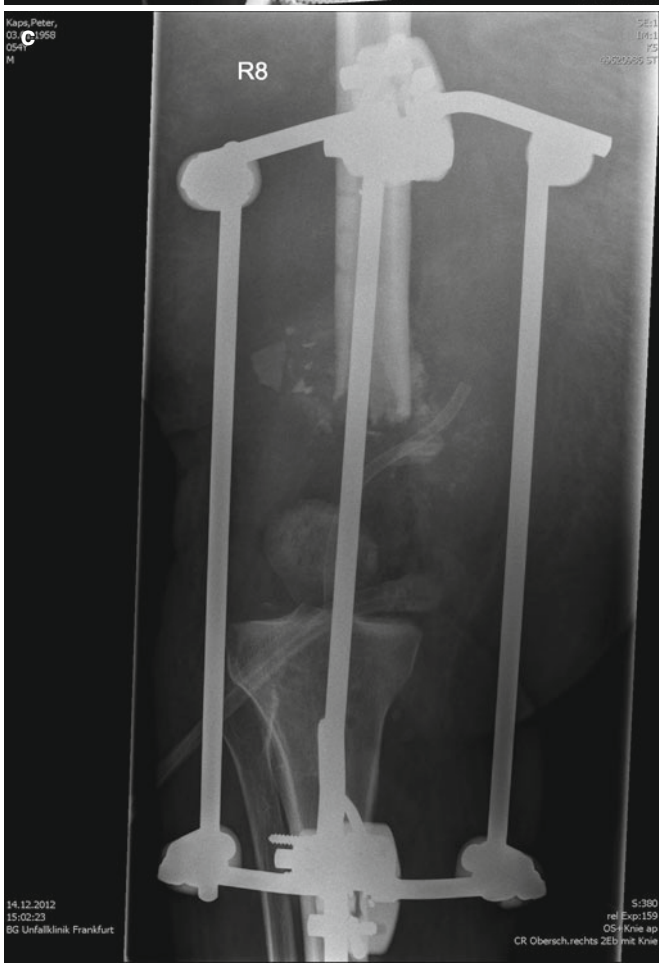


Fig. 27.2 (continued)

Fig. 27.3 (**a**) Polytrauma patient with multiple rib fractures on the right with lung contusion, pleural effusion, scapular fracture, 2nd grade open distal femur fracture (AO/OTA 33-C3), tibia shaft fracture left, iatrogenic injury to the popliteal artery. Comorbidity: Obesity, hyperlipoproteinemia, atrial fibrillation and antithrombotic therapy, coronary artery disease, hypertension, hypertensive heart disease, nicotine abuse. (**b**) Infected plate fixation of the right femur after internal fixation using a distal femoral plate. (**c**, **d**) Plate removal, femoral segment resection, shortening osteotomy, sequestrectomy, temporary implantation of a 30-bead refobacin palacos chain, removal of tibial nail. Placement of a joint-bridging external fixator, temporary soft-tissue coverage. (**e**–**h**) Distal femoral replacement with knee arthrodesis module (KAM, Manufacturer Brehm, femoral Ø 18, length 200, distal Ø 17, length 200) AP and lateral radiographs of the femoral and tibial implants. (**i**) Clinical picture 6 months post-operatively


a
R


b
R


c
R8
14.12.2012
15:02:23
BG Unfallklinik Frankfurt

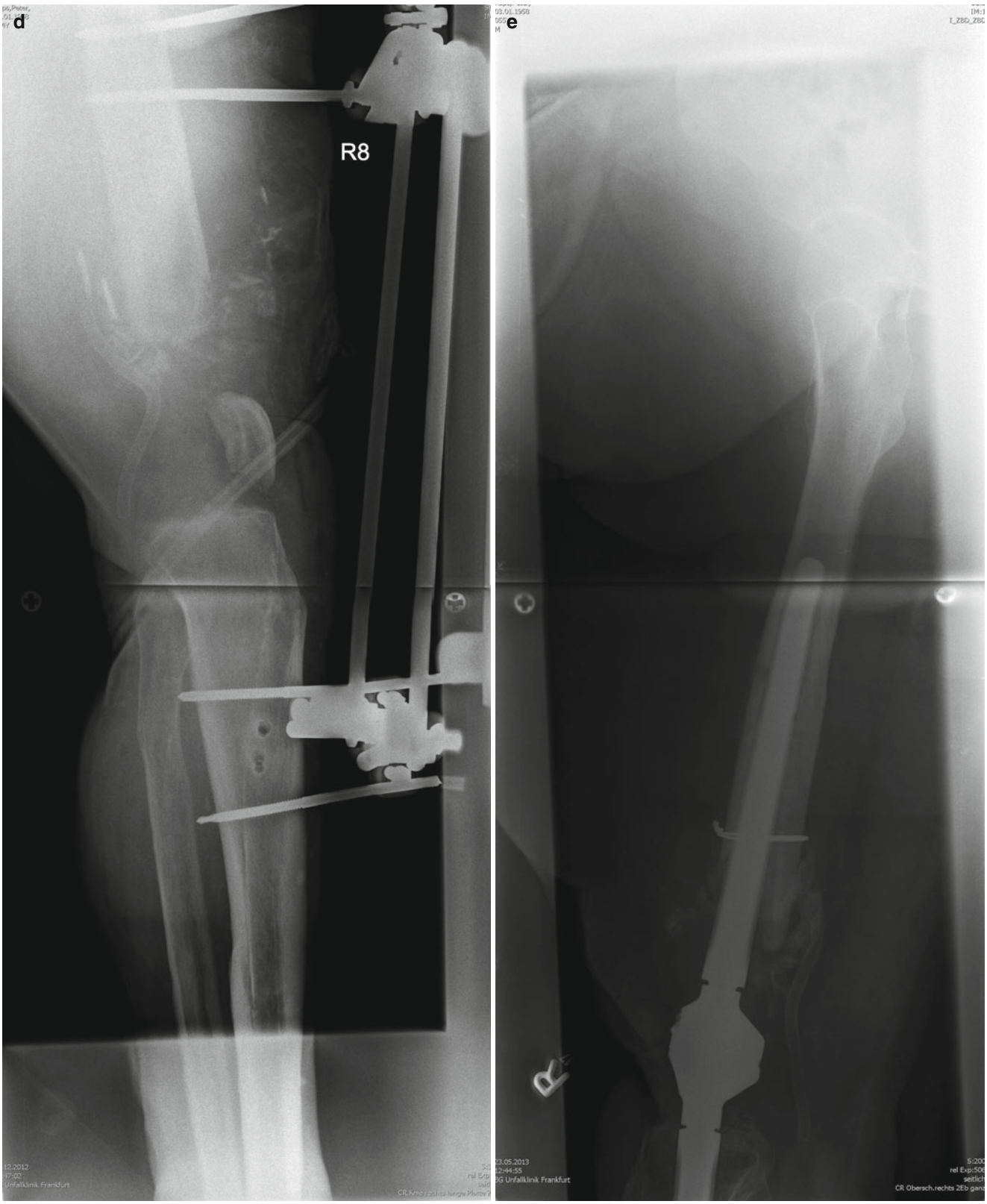


Fig. 27.3 (continued)

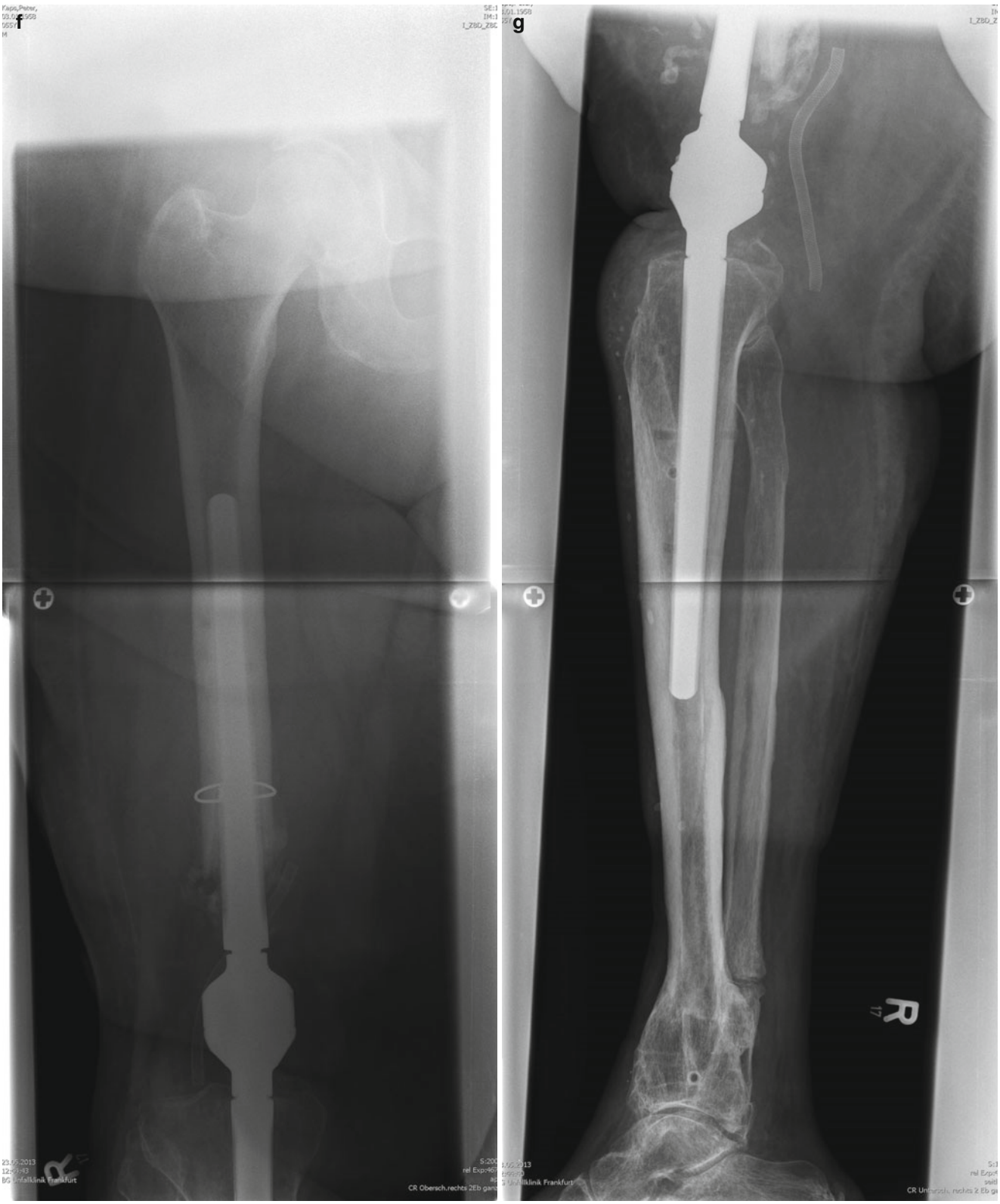
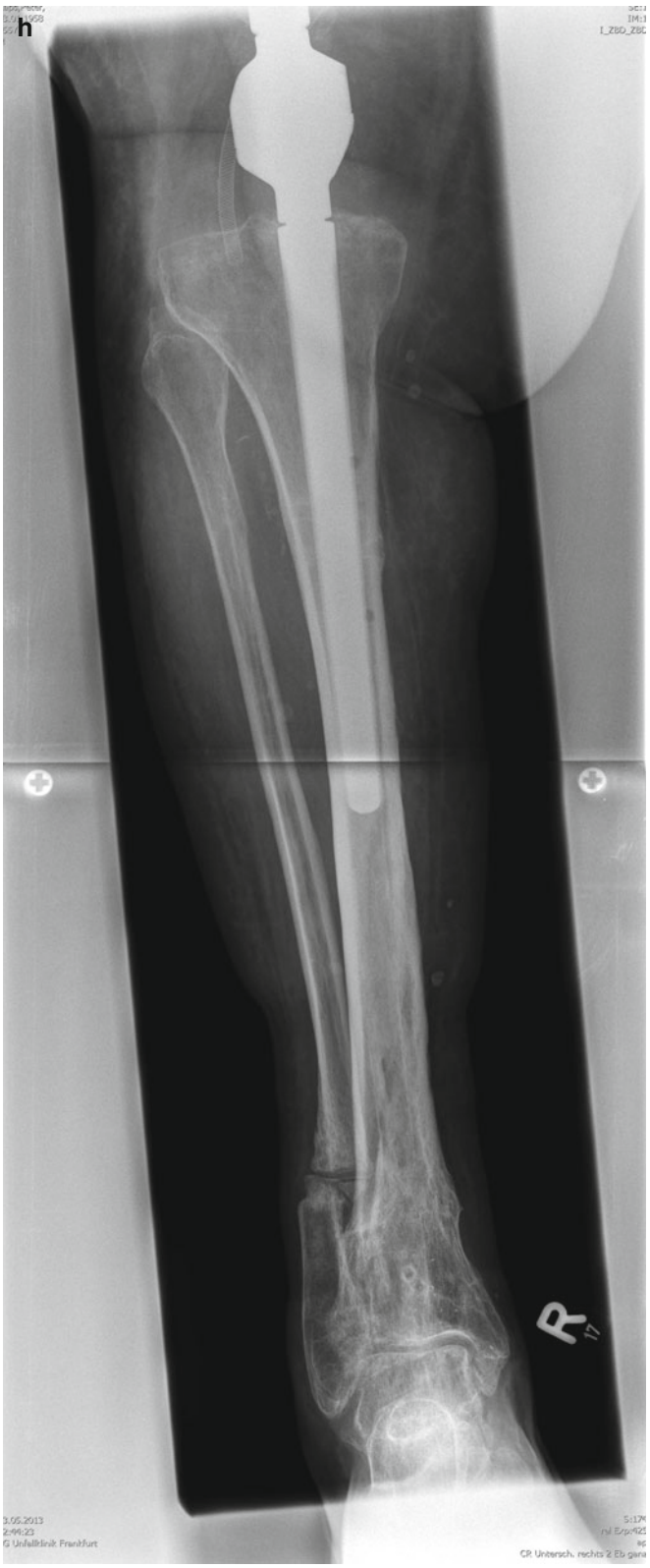


Fig. 27.3 (continued)



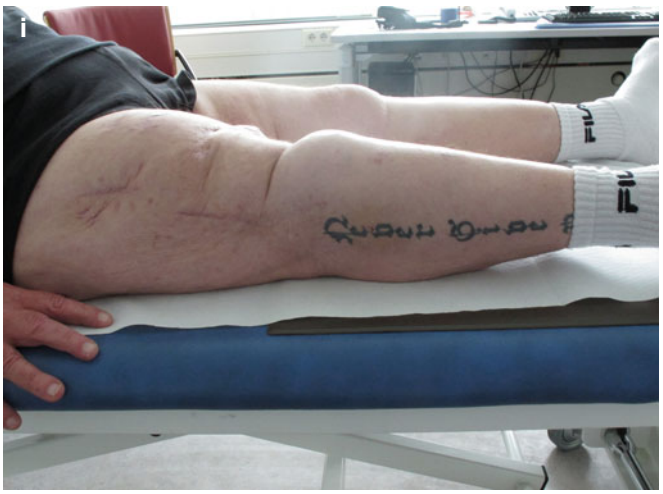


Fig. 27.3 (continued)

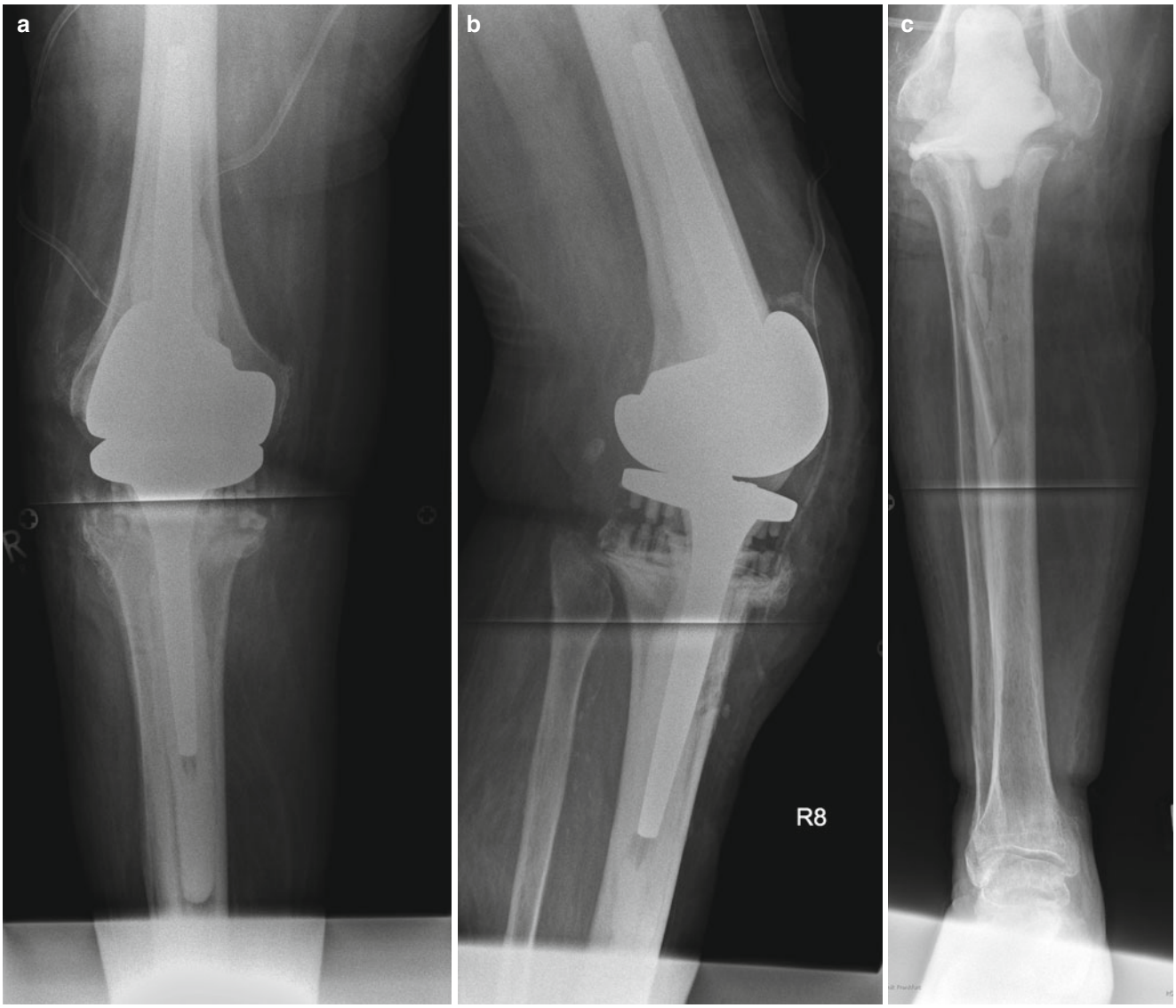


Fig. 27.4 Seventy-three year-old man, total knee arthroplasty, early infection, unsuccessful preservation attempt. Comorbidity: Diabetes mellitus with polyneuropathy, nephropathy, hypertension, CVA 2005, COPD, allergic syndrome. (**a**, **b**) AP and lateral radiographs of the knee joint. (**c**, **d**) Explantation of the total knee endoprosthesis and insertion of an antibiotic spacer. (**e**, **f**) Implantation of a T2 compression nail after removal of the spacer. (**g**, **h**) Infection recurrence and loosening of the arthrodesis nail. (**i**, **j**) Removal of the arthrodesis nail and implantation of a KAM. AP and lateral radiographs 12 months post-operatively

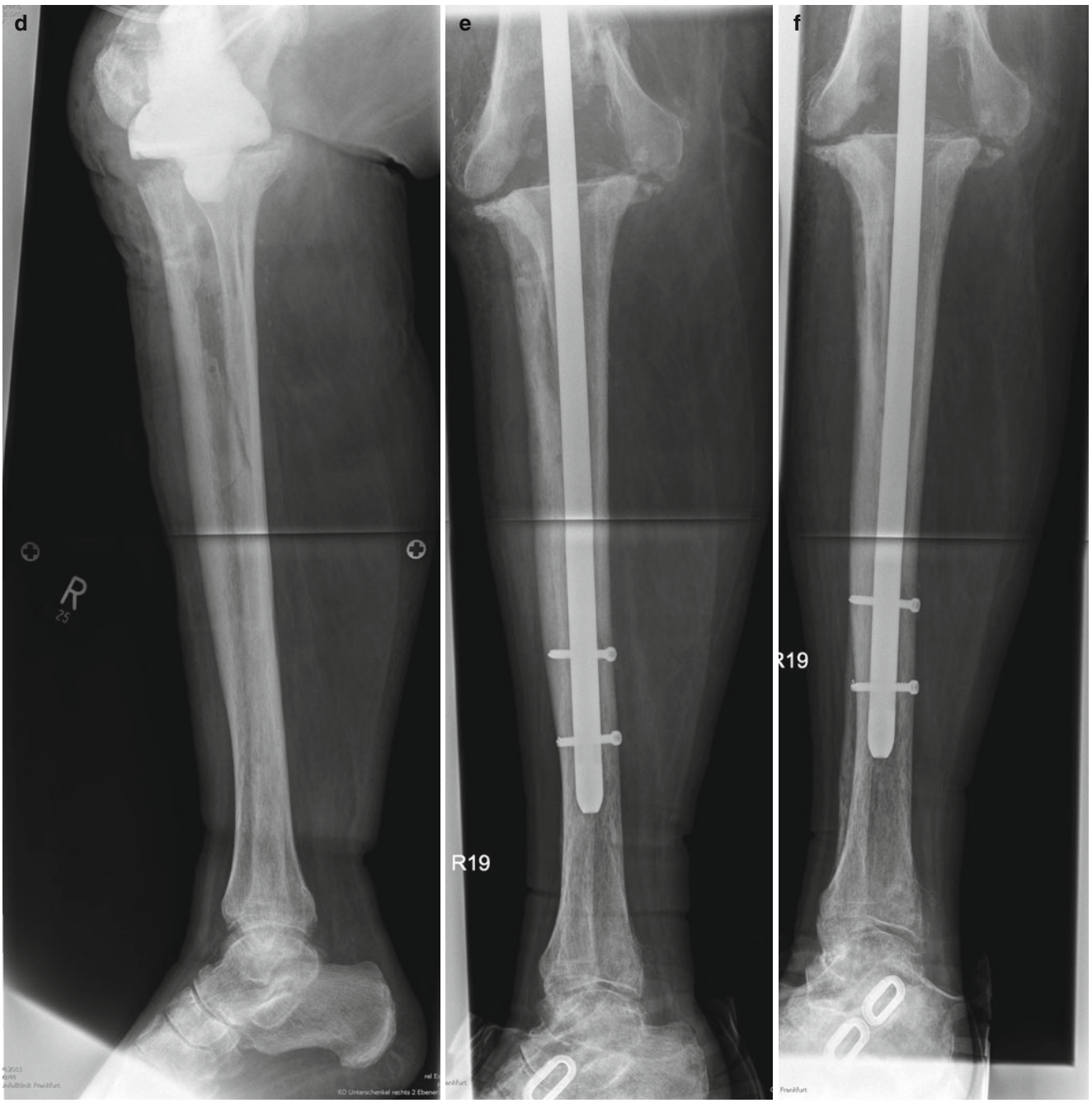


Fig. 27.4 (continued)

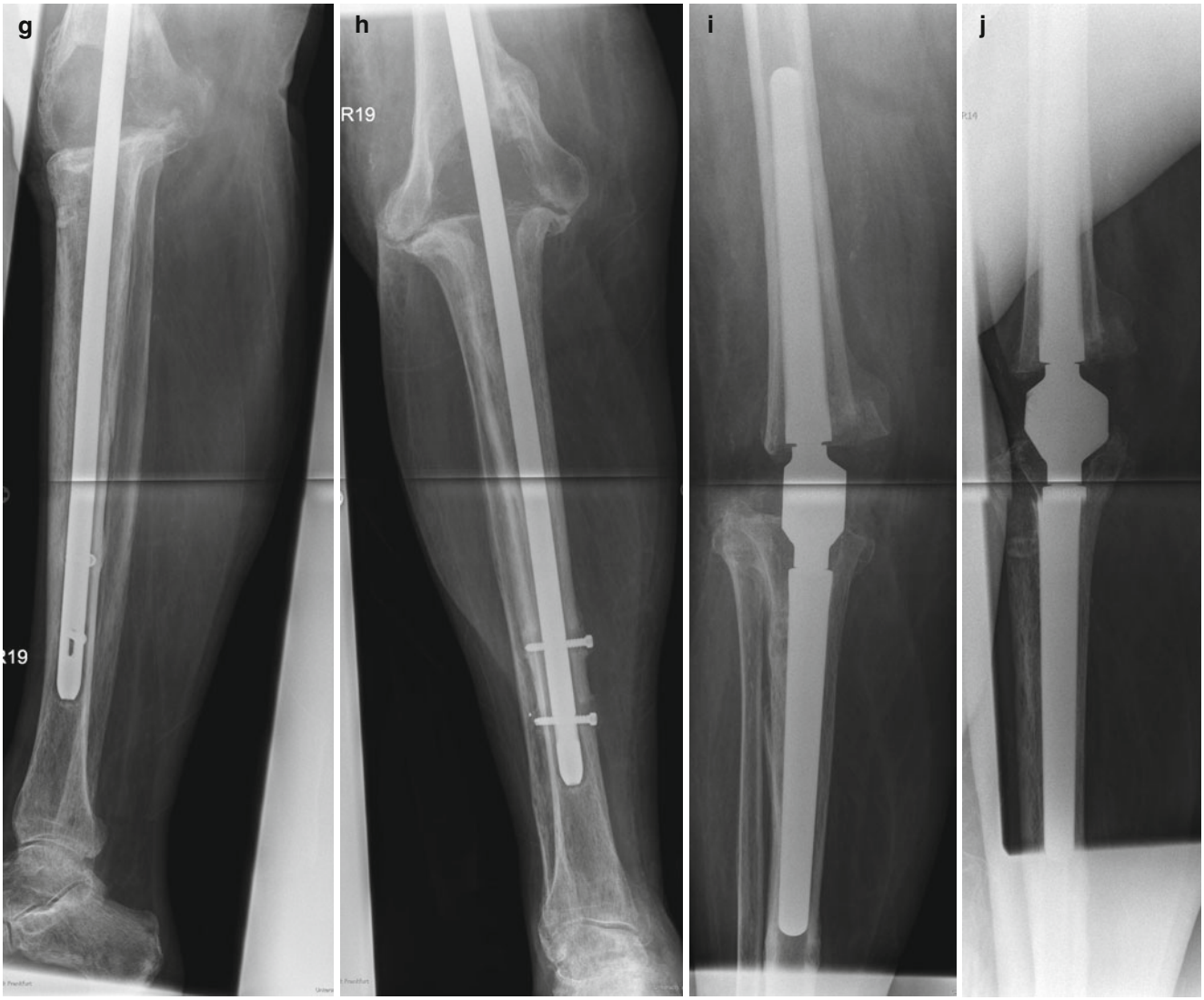


Fig. 27.4 (continued)

27.6.2.1 Planning

For preoperative planning, full-length femur and leg radiographs in 2 planes with ruler are necessary. Planning of the length and the diameter of the endoprosthesis module can be carried out using stencils or on the PC.

27.6.2.2 Procedure

The procedure is performed with the patient in the supine position on a radiolucent operating table with a tiltable leg section.

An anteromedial skin incision is preferred; however existing incisions should be used with scar excision. Next the skin and subcutaneous tissue flap is mobilized, with opening of the capsule and ligament apparatus and the resection arthroplasty. Less vascularized scar tissue and portions of tendon as well as sclerotic or parts of bone suspected to be infected should be resected. Patellar tendon dis-insertion is an indication for patellectomy with suturing under the distal resection edge of the quadriceps tendon. Next there is free dissection of the distal femur and proximal tibia. Precautionary a cerclage wire can be placed around both bones to prevent fissure and fracture formation.

Canal preparation is preferentially begun with the tibia. The approach is in the projection of the tibial shaft axis, usually approximately 1.5 cm posterior to the tuberosity. If there is no major axis deviation on the tibial side, and according to preoperative planning, a straight shaft of length 140 mm should be provided. The reamers are marked with notches for the joint line as well as 30 mm distance, which corresponds to half of the module. Canal preparation continues using reamers of increasing diameter until sufficient cortical contact has been produced. Next hammering in the test-shafts is performed, normally the diameter corresponds to that of the last reamer. The selection of the appropriate diameter requires a certain amount of experience and caution, particularly when dealing with osteoporotic bone. Correct positioning should be checked with the image intensifier. The test shaft is left in the canal.

Next the femoral canal is prepared, similarly in a projection of the femoral axis. The guide wire is inserted and the canal is reamed with flexible reamers and heads with increasing diameters until there is sufficient cortical contact in the isthmus area. The test shafts are driven into the canal, with the final size often 2–3 mm larger than the final reaming head. When correctly seated, with the position also controlled using the image intensifier, the distance between the ends of both cones is measured. This must be at least 3 cm. Leg length determination is performed. If the distance between the shafts is too large, they must be replaced with the next largest diameter. A rule of thumb is that 1 mm diameter increase allows approximately 2 cm less entry of the shaft, and thus that amount of length is added. If the implant is counter-sunk within the bone, the cutter can be used for the knee coupling. A sample module is then attached and the leg length as well as rotation is checked.

If there is an acceptable fit, all test components can be removed and replaced with the definitive original implants in corresponding sizes. Next, the fusion elements will be attached and an additional trial reduction is performed. When everything is seated properly, the module is locked and secured with screws, which are tightened with the torque wrench. The coupling of the module is reapplied and secured with two 7 mm bolts, which are also tightened with the torque wrench. Final fluoroscopy is performed in two planes. Wound closure should be very carefully performed. In some cases, further mobilization of the skin-subcutaneous flap is necessary.

27.6.2.3 Complications

Incorrect selection of the femoral or tibial entry portal, or insertion of shafts with oversized diameter can lead to femoral or tibial shaft rupture. This can entail an additional internal fixation procedure or transfer to another independent procedure. We have previously mentioned the advantage of placing preventive cerclages around the femur and tibia.

Because of the approach, injuries to the popliteal neurovascular structures as well as the peroneal nerve are possible.

Malrotation as well as leg length discrepancies (shortening or lengthening) should be avoided through repeated intraoperative clinical and radiological controls. Wound healing disturbances can require plastic coverage or can lead to above knee amputation. Cases of persistent secretion or recurrent seroma formation are generous indications for early revision.

Implant loosening or fracture are rare. The implant can be removed only with great difficulty. Thus, in the case of recurrent infection an above knee amputation is likely to be required.

27.6.2.4 Post-operative Care

Prophylaxis is carried out with the last effective antibiotic. In cases of suspected persistent infection, antibiotic therapy should be continued until cultures from intraoperative tissue probes of the medullary canal and capsule are completed. If the cultures show pathogen growth, therapy should be continued for 6 weeks.

Immediate weight-bearing to 20 kg can be implemented for 6 weeks, after which it can be increased to full weight-bearing according to radiographic controls.

27.7 Our Results

Between September 2007 and June 2013, 106 patients were treated with knee arthrodesis as a limb-sparing procedure after therapy-refractory infection of an artificial knee. There were 56 men averaging 67.1 years (38–87 years) and 50 women averaging 70 years (27–91 years). In total, 145 procedures were performed.

During each procedure, at least two tissue probes were taken for microbiological examination. The most frequent pathogen was *Staphylococcus aureus*, followed by *Staphylococcus epidermidis* and methicillin resistant *Staphylococcus* species (MRSA). There was no evidence of microbial growth in 29 patients (27 %). For 47 patients (44.3 %), there were two pathogens, and for 18 patients (16.9 %) there were three or more.

A Hoffmann II fixator was used in 42 cases, T2 IM compression nails (Stryker) in 35 cases, KAM (Brehm) in 24 cases, distance arthrodesis (Implantcast) in 4 cases, and the knee arthrodesis module (ESKA) in one case.

In one distance arthrodesis, there was recurrent infection with septic loosening, which required above knee amputation. Another amputation was required after unsuccessful arthrodesis with external fixator.

Twenty-five patients treated with external fixators achieved bony consolidation and were ambulatory without assistance. Ten required a weight-relieving orthosis. In 6 patients treated with external fixator, a weight-loading consolidation was not reached; however, because of limited mobility, no further measures were performed.

Of 35 patients treated with a T2 compression nail, bony consolidation was achieved in 33. Eleven had been previously treated with an external fixator. Two patients suffered recurrent infections. One of these patients was switched to a KAM arthrodesis with success (Fig. 17.4a–j).

Of the 24 KAMs (Brehm) placed, 23 achieved full weight-bearing and permanent recovery from infection. One patient suffered recurrent infection, which required above knee amputation.

Conclusion

Peri-prosthetic infections after implantation and revision of endoprosthetics are the most common indication for arthrodesis. For this, there are several procedures from which to choose. Patients should be informed in detail of the advantages and disadvantages of the procedure, as well as therapeutic alternatives.

In cases of good bone quality and minimal bone loss, the use of an external fixator is recommended. However, the application of external devices is limited in cases of osteoporotic bone. In addition, joint fusions carried out with external fixators are complication prone and uncomfortable for patients.

In cases of subdued infection with minimal bone loss, compression nail arthrodesis has also been effective for patients with reduced bone quality. For larger bony defects, implantation of a non-cemented knee arthrodesis module has yielded good results. Selection of indications and procedure type as well as the surgery itself in cases of injured and osteoporotic bone require extensive experience. The procedure should be carried out only in departments that are acquainted with the procedure and its specialized care.

References

1. Zinsmeister O. Über die operative Behandlung paralytischer Gelenke (Arthrodese). Dtsch Z Chir. 1887;26:498–520.
2. Bristow WR. President's address: arthrodesis. Proc R Soc Med. 1927;21:111–7.
3. Weil S. Die Arthrodese und Arthrorise. In: Ergebnisse der Chirurgie und Orthopädie. Berlin: Springer; 1931. p. 385–539.
4. Küntscher G, Maatz B. Die Technik der Marknagelung. Leipzig: Thieme; 1945.
5. Charnley J. Arthrodesis of the knee. Clin Orthop. 1960;18:37–42.
6. Freeman M, Charnley J. Arthrodesis. In: Arthritis of the knee. Berlin: Springer; 1980. p. 142–7.
7. Conway JD, Mont MA, Bezwada HP. Arthrodesis of the knee. J Bone Joint Surg Am. 2004;86-A:835–48.
8. Wasielewski RC, Barden RM, Rosenberg AG. Results of different surgical procedures on total knee arthroplasty infections. J Arthroplasty. 1996;11:931–8.
9. Hanssen AD, Trousdale RT, Osmon DR. Patient outcome with reinfection following reimplantation for the infected total knee arthroplasty. Clin Orthop Relat Res. 1995;321:55–67.
10. Bierwagen U, Walter G, Hoffmann R. Kniegelenksarthrodese-Lebensqualität und Vergleich der Methoden. Z Orthop Unfall. 2010;148:566–72.
11. Gray CF. Knee arthrodesis is most likely to control infection and preserve function followed failed 2 stage procedure for treatment of infected TKA. In: Presented at: Musculoskeletal Infection Society annual meeting, Philadelphia, 2–3 Aug 2013.
12. Damron TA, Mcbeath AA. Arthrodesis following failed total knee arthroplasty: comprehensive review and meta-analysis of recent literature. Orthopedics. 1995;18:361.
13. Isiklar ZU, Landon GC, Tullos HS. Amputation after failed total knee arthroplasty. Clin Orthop Relat Res. 1994;299:173–8.
14. Pring DJ, Marks L, Angel JC. Mobility after amputation for failed knee replacement. J Bone Joint Surg Br. 1988;70:770–1.
15. Waters RL, Perry J, Antonelli D, et al. Energy cost of walking of amputees: the influence of level of amputation. J Bone Joint Surg Am. 1976;58:42–6.
16. Husted H, Toftgaard Jensen T. Clinical outcome after treatment of infected primary total knee arthroplasty. Acta Orthop Belg. 2002;68:500–7.
17. Henkel TR, Boldt JG, Drobny TK, et al. Total knee arthroplasty after formal knee fusion using unconstrained and semiconstrained components: a report of 7 cases. J Arthroplasty. 2001;16:768–76.
18. Müller G, Exner I. 226. Das perioperative Risiko von Amputationen an der unteren Extremität. Langenbecks Arch Chir. 1987;372:866.
19. Jones RE, Russell RD, Huo MH. Alternatives to revision total knee arthroplasty. J Bone Joint Surg Br. 2012;94-B:137–40.
20. Munzinger U, Knessl J, Gschwend N. Arthrodese nach Knie-Arthroplastik. Orthopade. 1987;16:301–9.
21. Nichols SJ, Landon GC, Tullos HS. Arthrodesis with dual plates after failed total knee arthroplasty. J Bone Joint Surg Am. 1991;73:1020–4.
22. Bosworth DM. Knee fusion by the use of a three-flanged nail. J Bone Joint Surg Am. 1946;28:550–4.