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Knee arthrodesis by the Ilizarov method in the treatment of total knee arthroplasty failure

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ABSTRACT

Background: Currently, the main indication for knee arthrodesis is septic failure of a total knee arthroplasty (TKA). The purpose of this study was to evaluate the results of knee arthrodesis by circular external fixation performed in the treatment of TKA failure in which revision arthroplasty was not indicated.
Methods: The study involved 19 patients who underwent knee arthrodesis by the Ilizarov method. Clinical and functional assessments were performed, including Knee Society Score (KSS). A postoperative clinical and radiographic evaluation was conducted every three months until the end of the treatment. Postoperative complications and eventual leg shortening were recorded.
Results: KSS results showed a significant improvement with respect to the preoperative condition. Of the 16 patients in the final follow-up, 15 patients (93.7%) achieved complete bone fusion. Major complications occurred in patients treated for septic failure of TKA and most occurred in patients over 75 years of age; the mean final leg shortening was four centimeters.
Conclusion: In our experience, the Ilizarov method is effective for performing a knee arthrodesis in the case of extensive bone loss. At the same time, it is possible to correct the associated leg deformities or limb length difference. In addition, only the Ilizarov method provides a mechanical stimulus for bone formation and improves the quality of the bone and of the microcirculation, which enhances the host response against infection. Despite these attributes, knee arthrodesis by the Ilizarov method must be considered a 'salvage procedure' in cases of severe outcomes from knee surgery in which revision arthroplasty is not indicated.

1. Introduction

Knee arthrodesis is a widely performed surgical procedure which has well-defined indications [46,55,64,79], and the procedure represents the best choice for those patients with extensive bone loss and recurring knee infections (Table 1). The main goal of such a procedure is to gain a stable and pain-free lower limb with a low risk of reinfection and a better functional outcome compared to an above-the-knee amputation. Conway and colleagues reported that the mean Knee Society Score (KSS) following a

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Table 1
Indications and contra-indications of knee arthrodesis.

Indications	Contra-indications
Extensor muscle deficit	Contralateral knee amputation
Poor soft tissue coverage	Contralateral knee/hip arthrodesis
Extensive bone loss	Degenerative changes in ipsilateral hip/ankle
Recurring infections/highly virulent microorganisms	Severe degenerative spine osteoarthritis
Charcot knee joint	Life-threatening infection
Poliomyelitis sequelae	

successful knee arthrodesis is approximately 70 points [16], and that an acceptable functional outcome cannot be represented by a KSS of lower than 50 points [13,16,30,69,73]. Besides the functional outcome, Pring and colleagues demonstrated a lower energetic expense in patients with knee arthrodesis compared to those with under-the-knee amputation [57], with a significantly lower overload to the hip joint and the spine.

In the last decades, many surgical techniques have been proposed for performing knee arthrodesis: internal osteosynthesis, intramedullary nailing, and external fixation [6,55,64]. The aim of our work is to review these surgical techniques and present our experience with knee arthrodesis performed at our institution using the Ilizarov method.

2. Methods

Between 2005 and 2012 we treated 19 knees (seven right and 12 left) belonging to 19 patients (17 females and two males). The mean age of the patients at surgery was 75 years (range: 38–85). Fourteen patients (74%) had septic total knee arthroplasty (TKA) loosening, three patients (16%) had revision TKA failure for extensor apparatus deficit and aseptic loosening, and two patients (10%) had a fracture at the previous arthrodesis site. The mean time between last surgery and knee arthrodesis performed by our unit was 14.2 months (range: one to 42.8). All of the patients were seen at our outpatient clinic, and before surgery underwent preoperative clinical controls: plain radiograph films, evaluation by an anesthesiologist, cardiology evaluation, and thorax radiograph (for patients older than 55 years or for smokers). For all patients we used the KSS to assess the clinical and functional preoperative status (we used 0 instead of negative values): the mean values were, respectively, 11.63 (range: 0–27) and 3.95 (range: 0–25). For those patients with septic TKA failure, we used the Cierny–Mader classification introduced by the University of Texas Medical Branch (UTMB) [14]. According to such classification, we had 15 cases (94%) with stage B (14 type 4, and one type 3), and also one case (six percent) with stage C type 4.

We used the Anderson Orthopaedic Research Institute (AORI) classification proposed by Engh [22–25,56] to assess the bone defect of the femur and the tibia at the time of the prosthesis removal during surgery. According to such classification, we had two cases (12%) with moderate bone loss after aseptic TKA failure (AORI degree: 2B), 15 cases (88%) with severe bone loss (AORI degree: 3), 14 cases after septic TKA failure, and one case after aseptic TKA failure.

2.1. Indications for knee arthrodesis

In our clinical practice knee arthrodesis was shown to be the best treatment choice in those patients with local compromise of the bone due to infection (Cierny–Mader stage B or C and types II, III, and IV), extended bone loss for which TKA or TKA revision could not be performed (AORI type 2 or greater), poor soft tissue coverage, extensor apparatus deficit associated with recurrent infection and/or extended bone loss. In patients with less-severe compromise of bone and soft tissues, TKA or TKA revision was taken into consideration. No other surgical techniques other than circular external fixation were used to perform knee arthrodesis.

2.2. Surgical technique

All of the patients were treated under general anesthesia by the same surgeon (A.K.), using the same surgical technique. The technique comprised an anterior approach to the knee through the previous skin incision, removal of prosthetic components, spacers, or cement, accurate bone and soft tissue debridement, preparation of the arthrodesis bone surfaces using an osteotome, apposition of the bone surfaces to achieve maximum bone contact, temporary arthrodesis and stabilization using two percutaneous crossed 2.5 mm wires, and skin suture.

The procedure entailed application of a distal femoral ring, placed perpendicular to the femoral anatomic axis, fixed with three Kirschner wires and one or two five millimeter or six millimeter diameter half-pins, and application of a proximal femoral arch, fixed with three or four half-pins. Connection of the distal femoral ring and the proximal femoral arch was by threaded rods, and application of a proximal tibial ring, placed perpendicular to the tibial anatomic axis, was fixed with two or three crossed Kirschner wires and one or two five millimeter diameter half-pins.

The distal tibial ring was placed perpendicular to the tibial anatomic axis, four to eight centimeters proximal to the ankle joint, fixed with two crossed Kirschner wires and one half-pin. Connection of the tibial rings was by threaded rod, and connection of the

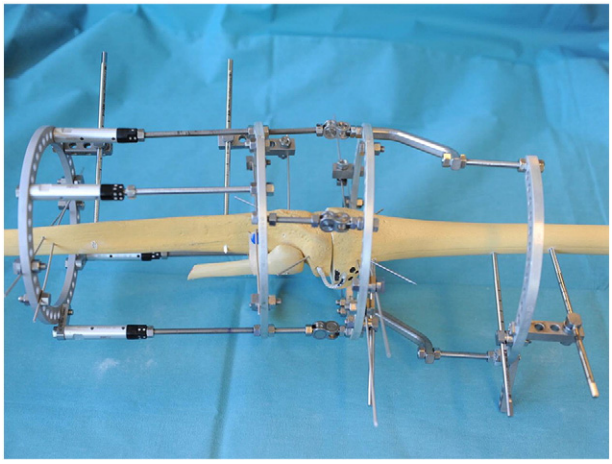

Figure 1. Circular external fixator: final frame.

femoral distal ring, and the tibial proximal ring was by hinges and threaded rods to allow further compression and axial correction at the arthrodesis site.

We applied two further tibial and femoral rings fixed with Kirschner wires and half-pins if simultaneous limb lengthening was required and removed the wires used for temporary arthrodesis. The final frame is shown in Figure 1, a detailed view of the hinges placed between the femur and the tibia is shown in Figure 2, and the osteotomy site for lengthening is shown in Figure 3.

3. Results

In 17 patients (89%) we used a tourniquet applied at the thigh; in two cases (11%) we did not use a tourniquet because of the poor vascular condition of the limb. The mean operating time was 3.25 h, which is lower than that reported by other authors (4.1 h according to Conway and colleagues [16]). After surgery we achieved complete contact between the femoral and tibial bone surfaces in full extension, with a five to seven degree valgus and three to five degree tibial external rotation. A mean four centimeter (range: two to seven) shortening was observed at the end of the surgery.

In the very first postoperative hours, pain was treated by continuous antalgic pump (morphine 30 mg + ketoprofen 200 mg + ranitidine 300 mg) for 24 h, then by non-steroidal anti-inflammatory drugs (NSAIDs) and mixed opioids/NSAIDs (by prescription and as needed). All patients were given a dressing change and proceeded to verticalization with progressive weight-bearing with crutches or canes on the operated limb on the second postoperative day, and discharged on the third postoperative day.

Major complications occurred in patients treated for septic TKA failure and mostly occurred in patients over 75 years of age. The complications we recorded and treated were the following: infection at the wire and half-pin insertion sites (14 cases, treated with dressing change and topic antibiotic therapy, mainly amoxicillin/clavulanate 875/125 mg twice a day for six days), loosening of transosseous elements (three cases, treated with the wire or half-pin removal), overload fracture at the arthrodesis site (two cases), temporary sensitivity loss around the knee (one case), soft tissue deep infection (one case, treated with oral antibiotic therapy, amoxicillin/clavulanate 875/125 mg three times a day for 14 days), ankle ankylosis (one case), and genu procurvatum (one case, treated with suitable hinges applied to the same frame used to perform the arthrodesis).

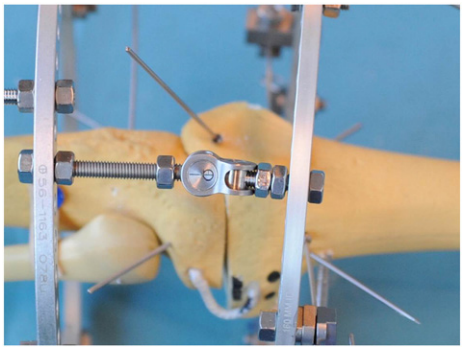

Figure 2. Hinges for axial correction and rods for compression.

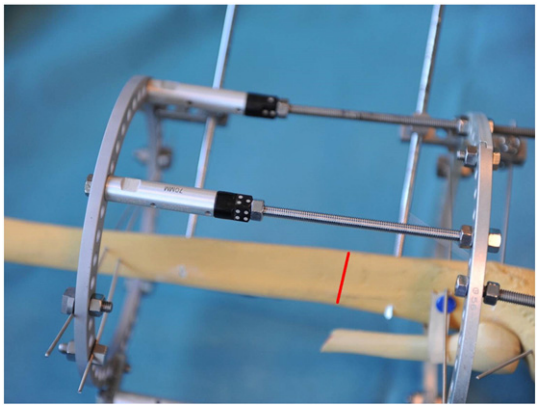

Figure 3. Osteotomy site for bone lengthening.

The two fractures occurred 20 and 45 days after the frame removal. In one case we performed another knee arthrodesis with the Ilizarov frame and a complete fusion was achieved after 12.1 months. The other patient refused to undergo further treatment because the non-union was painless and he could cope with the activities of daily living by wearing a brace.

We gained complete bone fusion in 15 patients (79%), and we had four cases (21%) of non-union (two cases due to infection recurrence and two cases due to fracture at the arthrodesis site). The mean time in frame was 11.7 months (range: six to 30.4); such time was longer in septic than in aseptic TKA failure patients (12.4 vs. eight months). The frame was removed when plain radiographs showed good contact between bone surfaces and a clinical stress test assessed good mechanical stability (both on antero-posterior and latero-lateral planes) at the arthrodesis site. In all cases the frame removal required a further surgery. At the time of the frame removal, nine patients (56%) could fully bear weight without crutches or canes, five patients (31%) needed them to walk, and two patients (13%) had not been walking because of their general medical condition. After the frame removal a knee brace was applied and the patients were educated to wear it all day and all night long, removing it only for personal hygiene.

The mean follow-up time was 36 months (range: one to 82). During follow-up, each patient underwent clinical evaluation at two and four postoperative weeks, and then on a monthly basis; before each clinical evaluation plain radiographs of the knee were performed to assess the contact between bone surfaces. At the end of the treatment the mean limb shortening was four centimeters (range: two to seven), which could be considered comparable with the mean shortening reported by other authors (2.5–6.4 cm) [3,10,18,52,55,59]. We used the KSS to assess the clinical and functional status at the end of the treatment (as with the preoperative assessment, we used 0 instead of negative values). The mean values were, respectively, 67.89 (range: 51–71, which corresponds to a +583% increase) and 55.89 (range: 0–70, which corresponds to a +44% increase).

4. Discussion

The main indication for knee fusion is the failure of a TKA due to infection, in which revision arthroplasty is not indicated. Arthrodesis allows the patient to live life with a stable, pain-free limb, with no limb length discrepancy, with a huge decrease in reinfection rate, and without considering the use of orthotics [6,8,50,52,53,64,68,76,81,82,83].

The reported fusion rates after a knee arthrodesis range from 80% to 100% in patients who have never undergone TKA [1,8,26,43,54,58,59,60,76,77], and dramatically fall to a value ranging from 27% to 80% in those patients with TKA infection [9,10,30,33,35,37,39,47,61,62,68,78,80,81,82]. Stiehl and Hanel reported their clinical experience, with a fusion rate as low as 21% [69]. The reason for this remarkable difference lies in the fact that in patients with no previous surgeries, rigidity and compression due to osteosynthesis coincide with the success of the bone fusion, while after many revision attempts, osteoporosis or osteopenia is present together with bone loss, and they are well known negative prognostic factors for bone fusion. Behr and colleagues also reported a decrease in the fusion rate when the failed arthroplasty involved the use of a constrained prosthesis (fusion rate ranging from 55% to 75%) compared to a fusion rate ranging from 50% to 95% in patients treated with non-constrained prosthesis [3,7,10,16,35,47,65,72].

Many researchers have attempted to determine the most important requisites to achieve a good bony fusion at the arthrodesis site. Currently, there is a general consensus regarding the importance of the main factors affecting the success of the procedure: rigid fixation [65,79], low extent of bone loss [60,52], and good bone contact between the femur and the tibia [16,35,46,79].

There are many surgical options for knee arthrodesis, such as internal fixation, intramedullary nails, and external fixation [3,19,29,47,65,80]. Among these, plates are the less commonly used, with very few cases are reported, with a successful fusion rate ranging from 40% to 100% [17,54,75]. Plates are also known to offer rigidity but not compression during weight bearing [53,58]. Most authors believe that internal fixation with intramedullary nails is the best treatment option because of its high rate of bone fusion, which ranges from 67% to 100% [1,2,17,19,21,27,28,38,40,46,47,49,51,54,59,66,75,79], a more acceptable

solution for the patient, with faster weight bearing [1,13,26,33,37,44,45,59,69,73,74,79,80]. Some authors reported the need for a bone graft in a variable percentage of patients ranging from five percent to 42% [17,47].

The main contraindication for the use of intramedullary nailing is infection, because of the high risk of propagation through the bone canal [46]. Well-known complications and disadvantages that can arise from this kind of treatment are reported [1,17,21,38,64,79,80], with an incidence rate ranging from 40% to 55% [47,79,80]. Examples are dissemination of infection, reactivation or maintenance of a latent infection, nail migration into the bone canal, nail breakage, delayed union or non-union, fractures of the distal tibia, neurovascular injuries, poor rotational control over the arthrodesis site, and significant blood loss during surgery and the first postoperative days. In addition to these complications, long femoral nails can be difficult to remove [13].

External fixation represents an alternative to intramedullary nailing. The main advantage, is that no materials or devices are implanted in septic tissues with a considerably lower risk of intramedullary dissemination of the infection [17,68,79]. The complications and disadvantages of external fixation are well known and include pin/wire infections, pin loosening, cosmetic discomfort, long treatment time, and frame maintenance [10,11,13,30,31,35,65,68,70,71,79]. There are many different kinds of external fixators, with different mechanical properties. Hak and colleagues demonstrated that better results are obtained with multiplanar fixators than with biplanar frames [36]. The reported rates of bone fusion in patients treated with external fixation range from 43% to 100% [18,32,34,35,36,48,52,62,68].

The Ilizarov circular frame, introduced in the early 1950s by the Russian surgeon Gavril A. Ilizarov, can be used for several purposes, including knee arthrodesis, and it presents some peculiar features [52,55]. It provides a mechanical stimulus for bone formation by progressive distraction and compression at the arthrodesis site; it improves the bone quality across the arthrodesis and offers mechanical stiffness without decreasing the bone stock. During the frame application, we prefer to use an osteotome to prepare the bone surfaces instead of an oscillating saw in order to create a greater hematoma, which represents a more suitable vascular environment for a better bone fusion.

Besides these features, circular frames provide more rigid fixation and the surgeon is given the opportunity to increase or decrease the frame stiffness by adding or removing transosseous elements and points of fixation [52]. The Ilizarov frame allows the alignment correction by using appropriate hinges, and in those patients with limb length discrepancy, it can be easily corrected with the same frame as that used for the arthrodesis.

As a general rule, many authors believe that external fixation should be avoided in patients with severe bone loss, because of a low rate of successful bony fusion [4,34,36,47,62,79]. However, the Ilizarov technique is the only external fixation method able to elevate this rate up to 93%–100% [18,52,55,79], though it presents a higher complication rate [32,55,79].

Many classifications have been proposed to assess bone loss in the knee [15,20,41,63]. We preferred to use the AORI classification proposed by Engh because it allows a more precise evaluation of bone loss during surgery, immediately after the implant removal. Another important feature of this classification is the fact that it is widely accepted in both scientific articles and clinical guidelines, so it can be understood by colleagues dealing with clinical conditions where bone loss is present.

We arthrodesed the knee with a five to seven degree valgus orientation and a three to five degree intra-rotation of the tibia. Klinger and colleagues report the same valgus deformity with a five degree flexion, but with no tibial torsion [46]. Looking at the literature, it seems there is no global consensus regarding the best position in which to fix the knee [16]. Most authors prefer a neutral position (0° extension) in order to minimize the postoperative shortening of the limb, while others prefer a slight flexion (five to 10°) [12,30,67]. However, greater flexion (10–15°) allows more comfortable sitting and walking at the expense of a

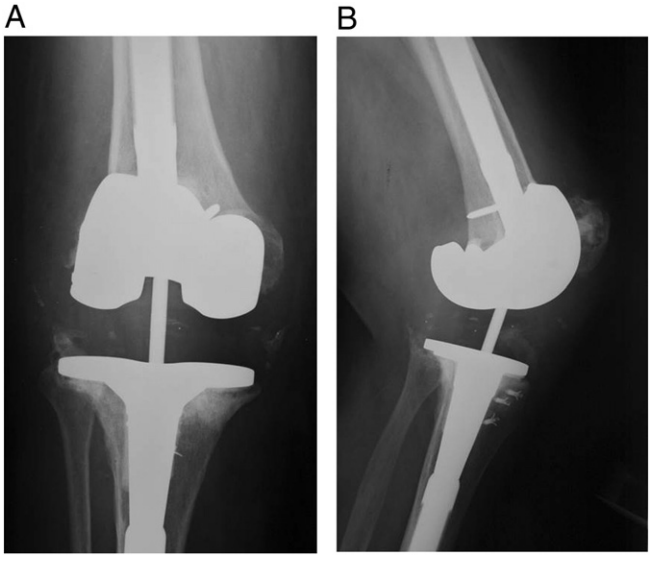

Figure 4. Preoperative radiograph.

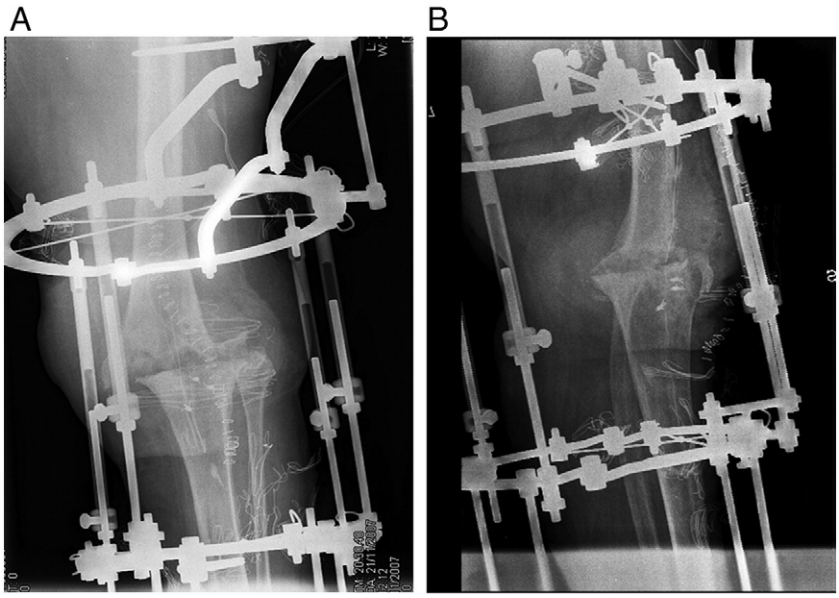

Figure 5. Postoperative radiograph.

greater limb length discrepancy [16] and energetic expense [67]. On the frontal plane the alignment judged as the best by many authors is a valgus orientation ranging from five degrees to seven degrees, which is easy to gain with an external fixator such as the Ilizarov fixator, while it is extremely difficult or impossible to gain with intramedullary nails which permit a two to five degree varus alignment, representing a mechanical disadvantage for the ipsilateral hip joint [59]. Other authors only report a flexion–external-rotation–valgus alignment at the arthrodesis site without indicating a specific numeric value [68].

In our experience, we always performed a single-stage surgery (prosthesis or spacer removal at the same time as the frame application). Many surgeons prefer a two-stage approach, which consists of a first surgery for the prosthesis/spacer removal followed by a six month antibiotic oral therapy followed by a two to four month resting period, and then the knee arthrodesis,

Figure 6. Radiograph after treatment.

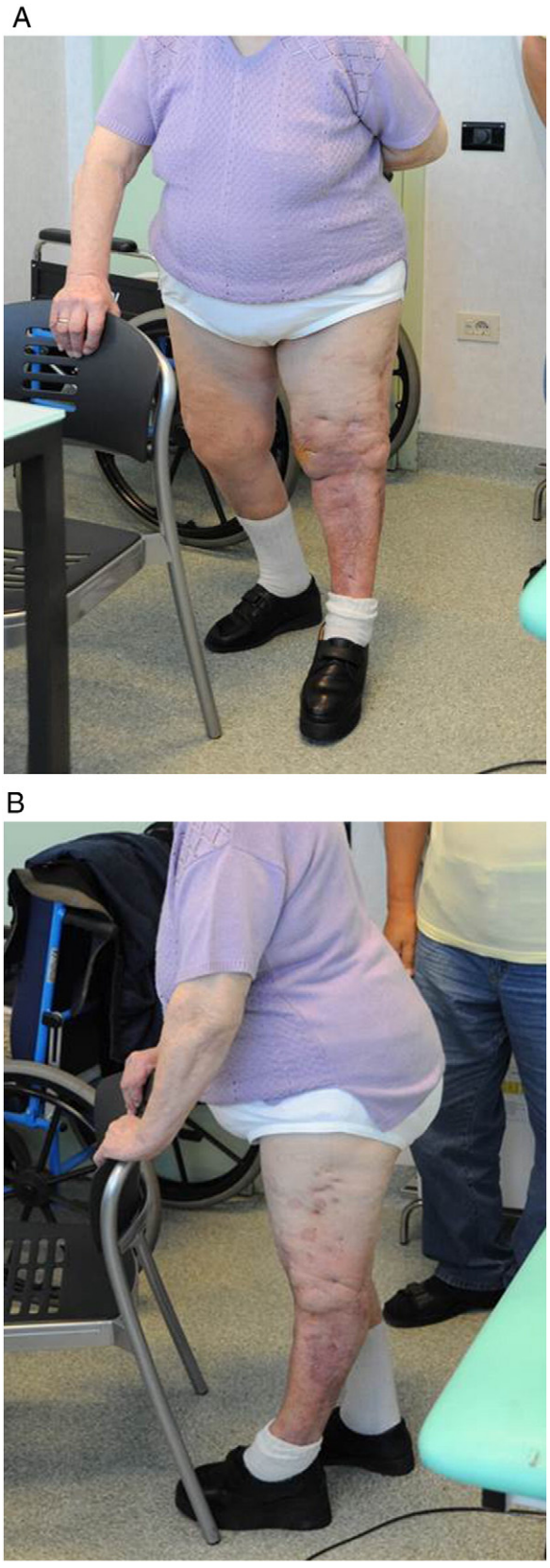

Figure 7. Patient with knee arthrodesis healed.

independent from the surgical technique used to gain it. The same authors report a greater fusion rate in those patients treated with a two-stage approach compared to those who underwent a single-stage surgery [16,21,79].

There is no consensus about the use of bone grafts while performing a knee arthrodesis. Knutson and colleagues reported that there are no statistically significant differences in final fusion rates in patients receiving bone grafts compared to those who do not [46,47]. With the Ilizarov method bone grafts are never needed to achieve bone fusion.

Another important factor affecting the success rate of bone fusion is the number of previous surgeries. Hanssen and colleagues reviewed many authors' experiences, calculating that patients with infection of a revision TKA have undergone an average of 13 surgeries before knee arthrodesis [37]. In their work, Damron and McBeath reported that even the microorganism involved in the TKA infection can affect the fusion rate, which is lower in patients with Gram-negative bacteria or mixed infections [17]. In the end, before performing a knee arthrodesis, every surgeon must take into consideration amputation, which is a more invasive and invalidating procedure for the patient. For this reason, amputation should always be avoided, but it could be considered a valid treatment option in those patients with life-threatening or persistent infections (class C according to the Cierny–Mader classification), or irreparable soft tissue and huge bone loss (type 3 according to the AORI classification). Many authors reported an amputation incidence after TKA ranging from 0.02% to 0.18%, which dramatically increases up to six percent in patients with chronic TKA infection [5,42,43,62]. The clinical case of a 75 year old female with revision TKA failure for extensor apparatus deficit and aseptic loosening is shown in Figure 4 (preoperative radiograph); Figure 5 (postoperative radiograph), Figure 6 (radiograph after treatment); and Figure 7 (patient with knee arthrodesis healed.)

5. Conclusions

Many medical conditions are known to require knee arthrodesis, and many surgical techniques are available to achieve this: internal fixation with plates or intramedullary nails and external fixation. The Ilizarov frame provides a mechanical stimulus for bone formation without the need for bone grafts, allowing the surgeon to increase or decrease the frame stiffness by adding or removing transosseous elements. In our experience, the Ilizarov method is a very effective technique that the surgeon can take into consideration in cases where knee arthrodesis is required, and it can also be used to correct associated deformities or limb length discrepancies.

Conflict of interest

No benefits of any form have been or will be received from a commercial party directly or indirectly related to the subject of this article. The authors did not receive grants or outside funding in support of their research or preparation of this manuscript. They did not receive payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. No commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, educational institution, or other charitable or non-profit organization with which the authors are affiliated or associated.

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