Revision Total Joint Arthroplasty

E. Carlos Rodríguez-Merchán
Editor

Springer

Revision Total Joint Arthroplasty

E. Carlos Rodríguez-Merchán
Editor

Revision Total Joint Arthroplasty

Springer

Editor
E. Carlos Rodríguez-Merchán
Department of Orthopedic Surgery
"La Paz" University Hospital
Madrid
Spain

ISBN 978-3-030-24772-0 ISBN 978-3-030-24773-7 (eBook)
https://doi.org/10.1007/978-3-030-24773-7

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

In the twenty-first century, we are observing a greater longevity of the population, which in developed countries reaches an average of 80–85 years. This circumstance means that many elderly patients, from approximately 65–70 years of age, suffer from painful degenerative osteoarthritis (OA), especially in the hips and knees and to a lesser extent in other joints (shoulders, elbows, ankles). However, degenerative OA is not the only form of OA that the aforementioned large articulations can present.

When the conservative treatment of OA fails, elderly patients will need a primary total arthroplasty of the damaged joint. The goal is to relieve the intense pain associated with the problem and to improve the quality of life of patients for the remainder of their lives.

Contemporary primary total hip arthroplasties have a duration of 20–25 years, whereas those of the knee last approximately 15–20 years. Primary arthroplasties of the other large joints do not maintain such a long survival, but they help to alleviate the intense pain and functional disability that advanced OA produces. To deal with the problem, we must better understand the causes and risk factors that cause primary total joint arthroplasties to fail. Our goal is to delay as long as possible the need for a revision total joint arthroplasty. Unfortunately, it is common for total joint prostheses to ultimately need to be revised. Therefore, it is essential to understand the surgical technique of revision arthroplasty, as well as its possible complications and results.

In this book, the expert authors analyze the causes of and risk factors for the failure of primary arthroplasties of the shoulder, elbow, hip, knee, and ankle, based on their experience and an exhaustive literature review. They also review the surgical technique of revision arthroplasties of the aforementioned joints and finally their results and potential complications.

The intention of all the authors of this book is to provide useful knowledge to orthopedic surgeons who encounter cases of revision arthroplasty of shoulders, elbows, hips, knees, and ankles—which are increasingly frequent and which will be even more common in the near future.

My intention as editor of this book has been to capture in a single volume the most relevant information on total joint revision arthroplasty of the large joints of the anatomy.

Madrid, Spain — E. Carlos Rodríguez-Merchán

Contents

1 Revision Total Knee Arthroplasty: Epidemiology and Causes

E. Carlos Rodríguez-Merchán, Carlos A. Encinas-Ullán, and Primitivo Gómez-Cardero

1.1 Introduction

Although total knee arthroplasty (TKA) can effectively treat end-stage osteoarthritis, durability remains a concern. Longevity with current designs now approaches 90% at 20 years postoperatively [1, 2]. On the other hand, the predicted demand for primary TKA in the United States (US) will increase 673% by the year 2030 [3]. Furthermore, the demand is increasing for younger patients (i.e., those under 55 years of age), and patients are remaining active longer into their life [4, 5]. Thus, the demand for revision TKA (RTKA) is also expected to increase 601% by the year 2030 [3].

RTKA is an efficacious treatment for failed TKA but with less favorable results [6]. Taking into account the technical complexity and economic burden of RTKA procedures, it is compulsory to investigate current mechanisms and predictors of RTKA failure [6]. Revision surgery for failed TKA continues to pose a considerable burden for health-care systems [7]. The purpose of this chapter is to analyze the epidemiology, causes, and risk factors for RTKA.

1.2 Epidemiology

In 2018, Roche et al. analyzed 125,901 patients in the National US Private Payer Database to examine potential racial disparities in RTKA. Revision frequency and burden were the highest in African-Americans (12.4% and 11.1%, respectively) and were lowest in Asians (3.4% and 3.3%, respectively) [8]. TKA mechanical complications were the most frequent cause of revision, followed by periprosthetic joint infection (PJI), with contracture being the least frequent. The highest frequency of RTKA was in white patients younger than 40 years (27.1%). African-Americans (17.8%), other races (7.9%), and Hispanics (16.5%) had the highest frequency of revision in the 40- to 64-year age range. Among Asians (4.1%) and Native Americans (9.7%), revision frequency was highest in patients older than 65 years.

Choi et al. compared revision rates due to aseptic loosening between high-flex and conventional knee prostheses [9]. Some 2078 knees (1377 patients) were analyzed with at least 2 years of follow-up after TKA. Two types of implants were selected (LPS-Flex and LPS, Zimmer) to compare revision and survival rates and sites of loosened prosthesis components. The revision incidence of the LPS-Flex (4.9%) was significantly higher than that of the conventional prosthesis (0.6%). The 5-, 10-, and 15-year survival frequencies were 98.9%, 96.2%, and 92.0%,

E. C. Rodríguez-Merchán (✉) · C. A. Encinas-Ullán
P. Gómez-Cardero
Department of Orthopedic Surgery,
"La Paz" University Hospital, Madrid, Spain

E. C. Rodríguez-Merchán (ed.), *Revision Total Joint Arthroplasty*,
https://doi.org/10.1007/978-3-030-24773-7_1

respectively, for the LPS-Flex and 99.8%, 98.5%, and 93.5%, respectively, for the LPS. The survival incidence of the high-flex prosthesis was significantly lower than that of the conventional prosthesis, especially in the mid-run period (range, 5–10 years). The loosening frequency of the femoral component was significantly higher in the LPS-Flex prosthesis. The LPS-Flex had a higher revision incidence due to aseptic loosening than the LPS prosthesis in the population series with a long follow-up. The LPS-Flex should be used cautiously, taking into account the risk of femoral component aseptic loosening in the mid-run (range, 5–10 years) follow-up period after the initial surgical procedure [9].

1.3 Causes and Risks Factors for Revision

In 2017, Delanois et al. analyzed the epidemiology of RTKA in the United States. They found that infection was the most frequent cause of RTKA (20.4%), closely followed by mechanical loosening (20.3%). The most frequent RTKA procedure performed was all-component revision (31.3%) [7]. According to Roche et al., mechanical complications of the articular prosthesis were the most frequent cause of revision, followed by PJI, with contracture being the least frequent [8].

In 2018, Postler et al. analyzed 312 patients who underwent 402 RTKAs; 89.6% of these were referred to their center for revision surgery [10]. In 289 (71.9%) patients, this was the first revision surgery after primary TKA. The majority of the first revisions were late revisions (73.7%). Some 113 (28.1%) patients had already had one or more prior revision surgeries. The most common reason for revision was PJI (36.1%) (Figs. 1.1 and 1.2) followed by aseptic loosening (21.9%) (Fig. 1.3) and periprosthetic fracture (13.7%) [10–13]. Other less common causes of revision RTKA were instability (Fig. 1.4), pain, polyethylene wear, restriction of motion (arthrofibrosis), extensor mechanism insufficiency, mechanical defect, and allergy [14–17].

In 2015 Rodriguez-Merchan et al. reported that RTKA with a rotating-hinge design provided substantial improvements in function and a reduction in pain in elderly patients with instability following TKA [14]. Table 1.1 shows the main causes (and approximate percentage) of revision total RTKA [10].

1.3.1 Periprosthetic Joint Infection

In 2012, Rodriguez-Merchan reported the risk factors for infection following TKA [11]. They were obesity, diabetes, a history of open reduction and internal fixation, male sex, remnants of previous internal fixation material, body mass index (BMI), congestive heart failure, chronic pulmonary disease, preoperative anemia, depression, renal disease, pulmonary circulation disorders, rheumatologic disease, psychoses, metastatic tumor, peripheral vascular disease, and valvular disease.

At 30 days, the overall percentage of surgical site infection is 1.1%, whereas the published rate of deep infection is 0.1%. The lifetime frequency of PJI after TKA ranges from 0.7% to 4.6% [18].

Evangelopoulos et al. have reported that PJI is the predominant cause of early failure of primary and revision TKA, followed by aseptic loosening, instability, pain, malalignment, and inlay wear [6]. Reinfection percentage of the septic primary TKAs was 5%. Infection was the major cause of a second revision, reaching as high as 50% in all cases. The outcomes of this study suggested that septic failure of a primary TKA is likely to occur within the first 2 years after implantation. Septic failure of primary TKA did not influence survival of the revision prosthesis.

Rhee et al. studied the risk factors for PJI, revision, death, blood transfusion, and longer hospital stay 3 months and 1 year after primary total hip arthroplasty (THA) and primary TKA [19]. They analyzed all primary THA and TKA cases between 2000 and 2014. A total of 10,123 primary THA and 17,243 primary TKA procedures were performed. With THA, the risk of PJI was higher in patients with heart failure and those

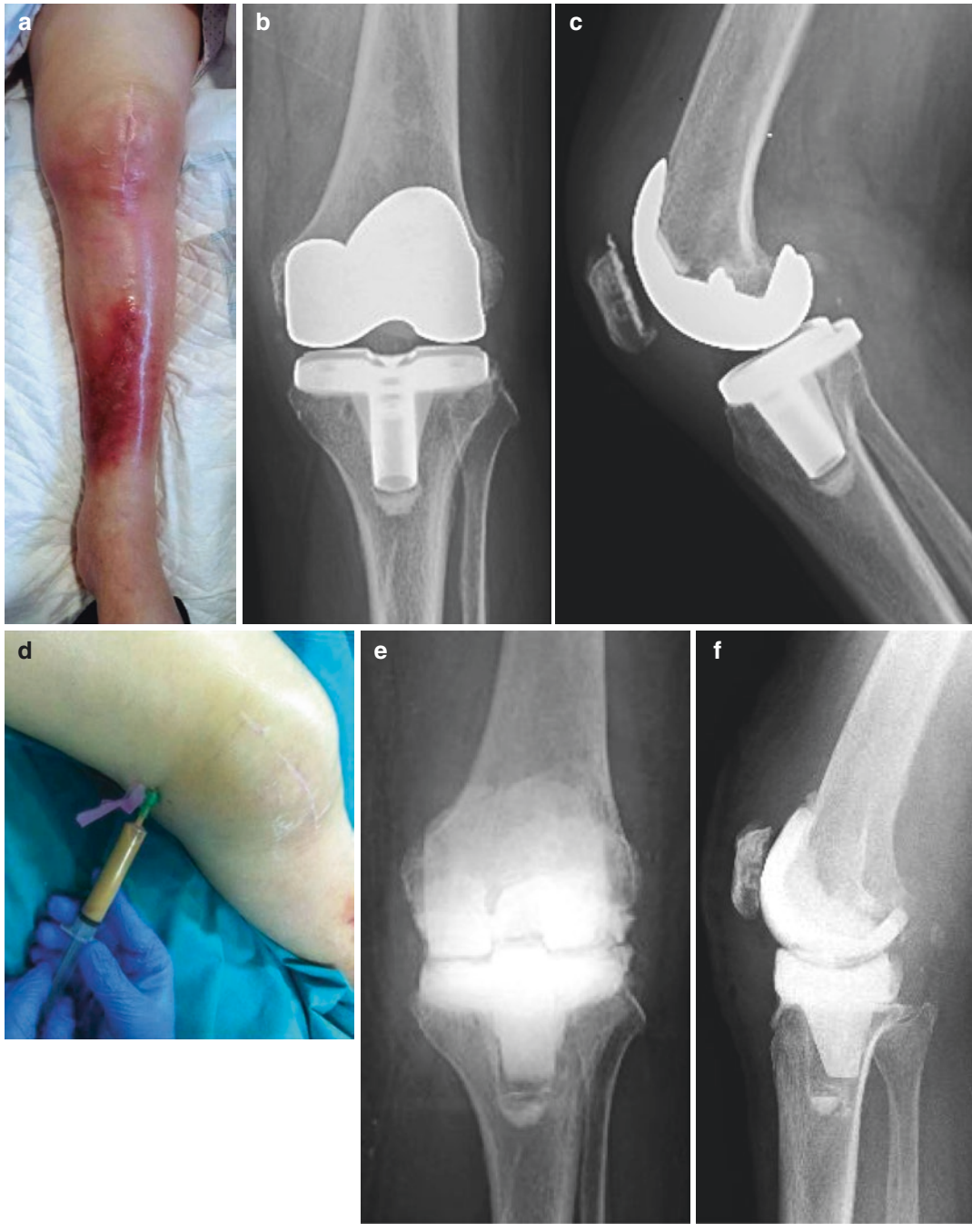

Fig. 1.1 (**a**–**f**) A 74-year-old woman had a TKA implanted in her left knee 9 months earlier due to very painful idiopathic osteoarthritis. She went to the Emergency Department (ED) because she had pain and inflammation in her operated knee together with redness in her leg for 2 weeks (**a**). *Staphylococcus aureus* was detected in the blood cultures performed. The knee radiographs performed in the ED were considered normal, both in the anteroposterior (**b**) and in the lateral (**c**) views. The joint puncture extracted frank pus (**d**), the same microorganism being cultured again in the joint fluid obtained. Performing a two-stage revision arthroplasty was decided. In the first stage, the infected prosthesis was removed, and an articulated spacer was implanted. In (**e**) the anteroposterior radiograph of the implanted spacer is shown, and in (**f**) the lateral view of the spacer can be observed

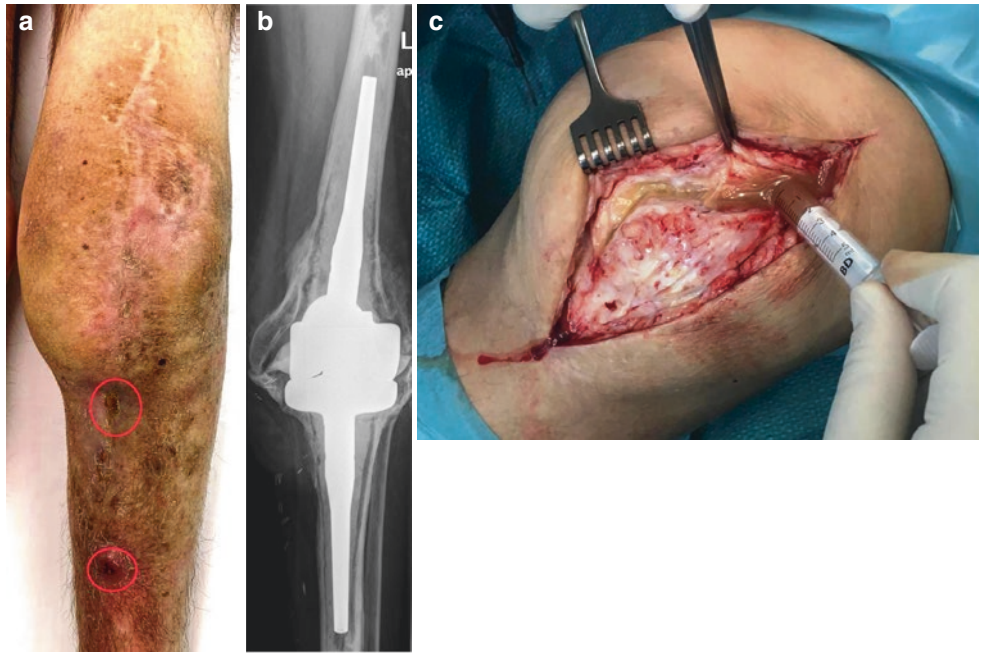

Fig. 1.2 (**a**–**c**) A 62-year-old man had undergone a two-stage revision arthroplasty 7 years previously for infection of a primary TKA implanted in his left knee. The patient consulted for pain and appearance of two fistulas in the proximal part of his leg (red circles) of several weeks' evolution (**a**). The radiographs performed during that consultation showed a severe loosening of the revision prosthesis (rotational hinge design) implanted 7 years before (**b**). It was decided to remove the infected revision prosthesis and implant a spacer through new surgery. Note the existence of frank pus in the infected knee in the intraoperative image

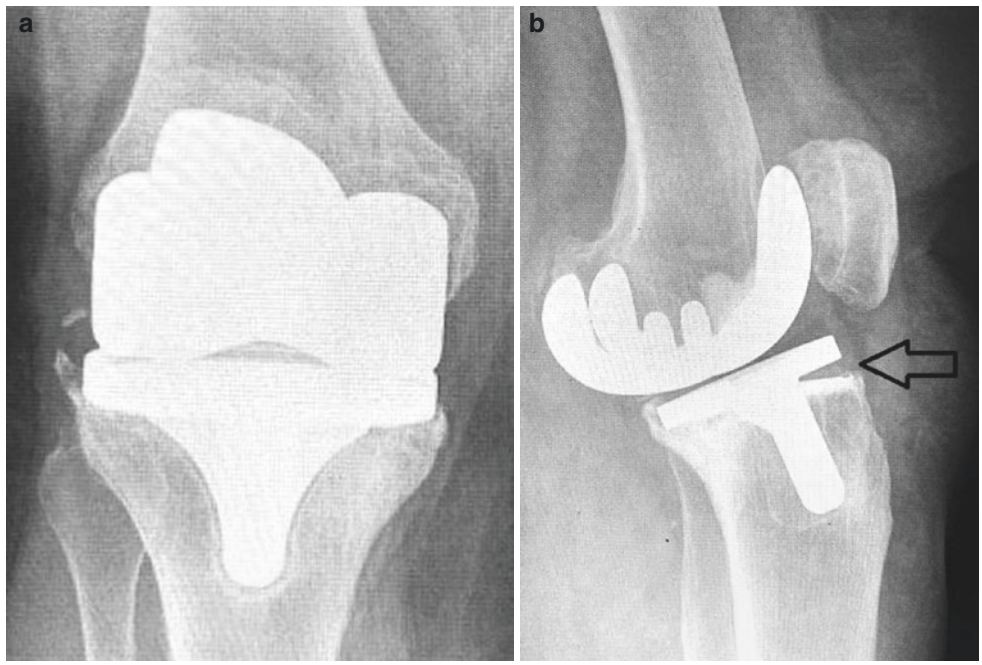

Fig. 1.3 (**a**, **b**) Aseptic loosening of primary TKA: (**a**) anteroposterior radiograph; (**b**) lateral view showing clear loosening of the tibial component (arrow). Performing a one-stage revision arthroplasty with a CCK (constrained condylar knee) prosthesis was indicated

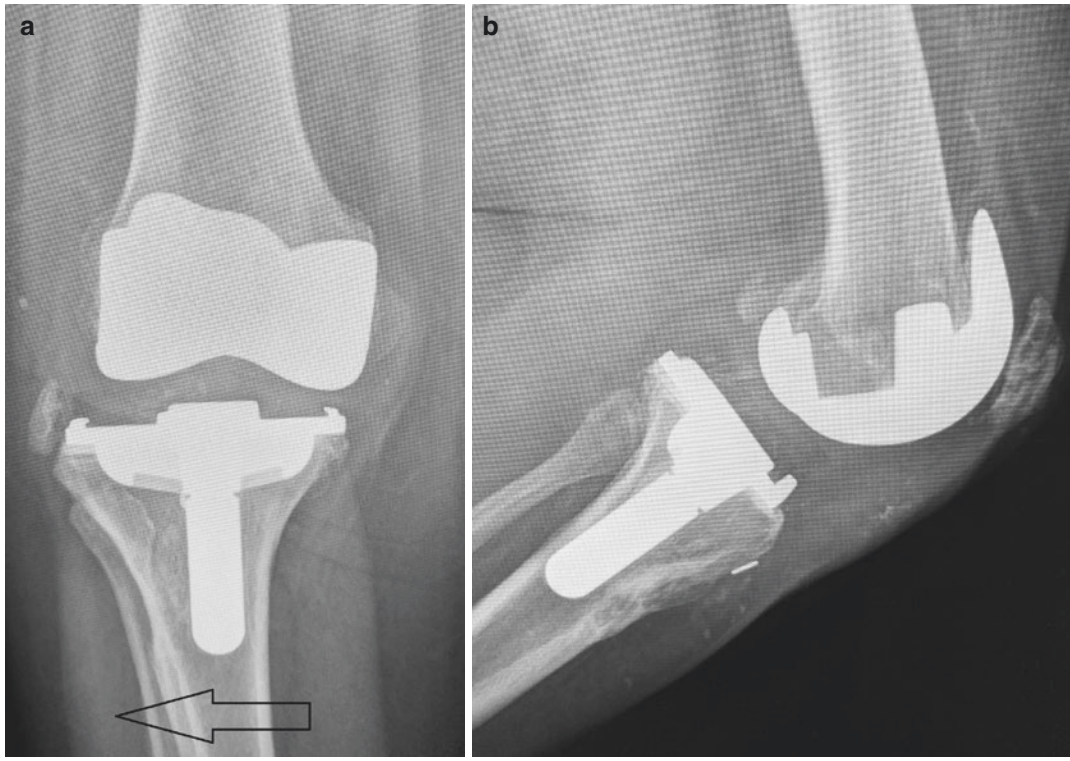

Fig. 1.4 (**a**, **b**) Instability after primary TKA. In the anteroposterior radiograph (**a**) a clear lateral displacement of the tibia with respect to the femur (arrow) is shown. In the lateral view, instability is not so evident (**b**). A one-stage revision arthroplasty with a rotational hinge design was indicated

Table 1.1 Causes (and approximate percentage) of revision total knee arthroplasty (RTKA)

Failure mechanism	Percentage
Periprosthetic joint infection (PJI)	36%
Aseptic loosening	22%
Periprosthetic fracture	14%
Instability	7%
Pain	6%
Polyethylene wear	5%
Restriction of motion, arthrofibrosis	4%
Extensor mechanism insufficiency	4%
Mechanical defect	1.5%
Metal allergy (nickel)	0.5%

with diabetes. For TKA, liver disease and blood transfusion were associated with a higher risk of PJI. Revision rates were higher among patients with hypertension and those with paraparesis/hemiparesis for THA and higher among patients with metastatic disease for TKA. Important risk factors for death included metastatic disease, older age, heart failure, myocardial infarction, dementia, rheumatologic disease, renal disease, blood transfusion, and cancer. Multiple medical comorbidities and older age were associated with higher rates of blood transfusion and longer hospital stay.

Matar et al. reported a higher failure frequency of two-stage revision for infected TKAs in significantly compromised (host-C) patients [20]. They performed a prospective consecutive series (level IV of evidence) of two-stage revisions of infected TKAs in host-C-type patients with a minimum 2-year follow-up using objective and patient-reported outcome measures. Thirteen patients were included, with a median 5-year follow-up (range 2–10). Median age was 68 years (range 59–73) at time of initial presentation. All patients were a type-C host, using the McPherson classification system. All patients had primary TKAs in situ, with proven chronic PJI; the infecting bacteria were *Staphylococcus aureus* in 5 of 13 patients, coagulase-negative *Staphylococci* in 5 of 13, and the remaining three patients had

mixed growth. All patients underwent a two-stage revision protocol. At the final follow-up, 9 of 13 patients were infection-free, achieving satisfactory results. Two patients had recurrent infections with different bacteria and were treated with suppressive antibiotics and salvage knee fusion, respectively. Moreover, two patients had chronic pain and poor functional results with insufficient extensor mechanism and significant bone loss; they later underwent salvage knee fusion. This study highlighted the challenge of treating infected TKA in physiologically compromised patients, with 9 of 13 (69%) achieving satisfying clinical results [20].

Fu et al. analyzed the correct timing of second-stage revision in managing PJI, as well as investigating dependable indicators and risk factors [21]. They reviewed and followed 81 TKA patients with infection who underwent two-stage revision in a 5-year period (2010–2014). The study included 56 men and 25 women; all patients were verified as PJI with the same phenotypic cultures. The average age was 64.8 (range 36–78) years, and the mean follow-up time was 46.5 (range 12–72) months after the second-stage surgeries. Serum C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), and intraoperative frozen section (FS) at the time of reimplantation were analyzed. The spacer detention time and antibiotic treatment time were compared. Ten patients underwent failed first- or second-stage surgical procedures. The overall success frequency was 87.7%. The intraoperative FS proved to be good indicator at the time of reimplantation; the sensitivity and specificity were 90% and 83.1%. Serum CRP and ESR showed a poor diagnostic value at the time of reimplantation. A typical bacterial infection, positive FS, and prior sinus were high-risk factors for failure of two-stage revision. Spacer detention time between 12 and 16 weeks had a higher success percentage than over 16 weeks. The main conclusion was that the proper timing of reimplantation should be linked with dissipation of clinical symptoms and negative intraoperative FS with spacer detention time at 12–16 weeks [21].

In 2018, Rajgopal et al. analyzed whether previous failed debridement, antibiotics, irrigation, and implant retention (DAIR) affect the outcome of subsequent two-stage revision performed for PJI after TKA [22]. They performed a retrospective study of 184 knees with completed two-stage RTKA for PJI, operated by a single surgeon in a 12-year period (2000–2011). The series was divided into two groups: those with prior failed DAIR (F-DAIR) (88 knees) and direct two-stage revision (96 knees). At an average follow-up of 5.3 years, the failure frequency was 23.86% (21/88 knees) in the F-DAIR group and 15.62% (15/96) in the direct two-stage revision group. A previous F-DAIR procedure was associated with approximately twice the risk of failure compared with direct two-stage surgery. Excluding PJIs caused by methicillin-resistant *Staphylococcus aureus*, methicillin-resistant *Staphylococcus epidermidis*, and *Pseudomonas* from analysis showed similar failure percentages between the two groups. The frequency of culture negativity and PJI with resistant organisms was higher in the F-DAIR group. The percentages of eradication of methicillin-resistant *Staphylococcus aureus* and *Pseudomonas* infection were much lower in the F-DAIR group. The main conclusion was that a failed previous DAIR led to higher failure percentages, lower functional results, and an increased risk of wound-related complications [22].

1.3.2 Obesity

In 2014, Rodriguez-Merchan reported that although some articles (with low grade of evidence) did not find that obesity adversely affected TKA outcomes, most found that obesity adversely affected TKA results [23]. Regarding complication rates and survival rates, obesity was demonstrated to have a negative influence on outcome after TKA. The improvements in patient-reported result measures, however, were similar irrespective of BMI. Regarding the impact of TKA on obese patients, an extra cost of $3050 has been reported per patient. Considering that 50% of the US population is obese and that 600,000 TKAs are implanted per year, the impact for the US health system could be as much as $915 million (300,000 × 3050). TKA in obese patients could

be justifiable because the functional improvements appear to be equivalent to those of patients with a lower BMI. However, in obese patients, the risk of complications is higher, and the prosthetic survival is lower. Moreover, TKA in obese patients has a significant impact on the healthcare system, which should be considered [23].

Tohidi et al. analyzed 10-year mortality and revision after TKA in patients with morbid obesity [24]. A total of 9817 patients were analyzed, aged 18–60 years, treated with primary TKA in a 5-year period (2002–2007). Patients were followed up for 10 years after TKA. Risk ratios of mortality and TKA revision surgery in patients with BMI > 45 (morbidly obese) compared with BMI ≤ 45 (nonmorbidly obese) were determined, making an adjustment for age, sex, socioeconomic status, and comorbidities. Approximately 10.2% (1001) of the group was morbidly obese. Patients with morbid obesity were more likely to be female than the nonmorbidly obese (82.5% vs. 63.7%) and showed higher 10-year risk of death but were otherwise analogous in characteristics. Approximately 8.5% (832) of the patients had at least one revision surgical procedure in the 10 years following TKA; the revision percentage did not vary by obesity. The main conclusion was that patients with morbid obesity ≤60 years had a 50% higher 10-year risk of death but had no difference in the risk of revision surgery [24].

1.3.3 Diabetes Mellitus

Being younger and male, having various comorbid conditions or greater diabetic severity, getting care at regional or public hospitals, and not having a diagnosis of degenerative or rheumatoid arthritis have been recognized by Tsai et al. as risk factors postoperative PJI after TKA for patients with diabetes. As for the risk of RTKA, postoperative PJI and being younger were significant risk [25]. This study examined the 2002–2012 data from Taiwan's National Health Insurance Research Database to conduct a retrospective cohort analysis of patients with diabetes older than 50 years of age who underwent TKA.

1.3.4 Pulmonary Disease

Gu et al. published the influence of chronic obstructive pulmonary disease (COPD) on postoperative results in patients undergoing RTKA [26]. A retrospective cohort study was performed using data collected from the American College of Surgeons National Quality Improvement Program database. All patients who underwent RTKA between 2007 and 2014 were identified and stratified into groups based on COPD status. The percentage of complications after surgery was assessed with univariate and multivariate analyses where appropriate. Patients with COPD developed more postoperative adverse events, including deep wound infection, organ infection, wound dehiscence, pneumonia, reintubation, renal insufficiency, urinary tract infection, myocardial infarction, sepsis, and death. Patients with COPD also returned to the operating room and had extended hospital stays. COPD was demonstrated to be an independent risk factor for development of wound dehiscence, pneumonia, reintubation, renal insufficiency, and renal failure. COPD was also recognized as an independent risk factor for unplanned returns to the operating room. The main conclusion was that patients with COPD are at greater risk for wound dehiscence, pneumonia, reintubation, renal insufficiency, and renal failure complications in the postoperative period than those without COPD. Although risks for independent adverse events remain relatively low, consideration of COPD status is an important factor to consider when selecting surgical candidates and evaluating preoperative risk [26].

1.3.5 Drug Abuse

Roche et al. have published that patients who abuse drugs are at increased risk for RTKA [27]. The Medicare database within the PearlDiver Supercomputer (Warsaw, IN, USA) was queried to identify 2,159,221 TKAs performed during an 8-year period (2005–2012). Drug abuse was subdivided into cocaine, cannabis, opioids,

sedatives/hypnotics/anxiolytics (SHAs), amphetamines, and alcohol abusers. There was a significant increase in the number of primary TKAs in users of cocaine, cannabis, opioids, SHAs, amphetamines, and alcohol. Amphetamine users had the fastest mean time to revision (691 days). At 30 days, 90 days, and 6 months postoperatively, cocaine users had the highest proportion of patients requiring RTKA (7%, 12%, and 20%, respectively); and at 1 year postoperatively, it was abusers of alcohol (38%). PJI was the most common cause of RTKA in all drug abuse/drug-dependent groups. Based on these outcomes, patients who abuse drugs are at increased risk for RTKA [27].

1.3.6 Opioid Use

Bedard et al. have found preoperative opioid use to be independently associated with a greater risk for early RTKA. Younger age, obesity, and smoking were also associated with increased risk. These findings support efforts to reduce inadequate opioid prescribing [28]. The Humana administrative claims database was queried to identify patients who underwent unilateral TKA during a 9-year period (2007–2015). Patients were followed for the occurrence of an ipsilateral revision procedure within 2 years. Preoperative opioid use was defined as having an opioid prescription filled within the 3 months before TKA. Age, sex, diabetes, obesity, chronic kidney disease, and anxiety/depression were also analyzed. A total of 35,894 primary TKA patients were identified, and 1.2% had had an RTKA procedure within 2 years. Some 29.2% of the patients filled an opioid prescription within the 3 months before TKA. Preoperative opioid users were significantly more likely to undergo early RTKA (1.6% vs. 1.0%); preoperative opioid use, younger age, obesity, and smoking were associated with early RTKA [28].

Weick et al. found that preoperative opioid use was associated with higher readmission and revision rates in TKA [29]. This prognostic study (level IV of evidence) showed that preoperative opioid use was associated with significantly increased risk of early revision and significantly increased risk of 30-day readmission after TKA. This study illustrated the increased risk of poor results and augmented postoperative health-care utilization for patients with long-term opioid use prior to TKA.

Law et al. have reported that cannabis use increases risk for RTKA [30]. A retrospective review of the Medicare database for TKA, RTKA, and causes was performed using Current Procedural Terminology and International Classification of Diseases ninth revision codes (ICD-9). Patients who underwent TKA were cross-referenced for a history of cannabis use by querying ICD-9 codes 304.30-32 and 305.20-22. Cannabis use was prevalent in 18,875 (0.7%) TKA patients, with 2419 (12.8%) revisions within the cannabis group. The revision rate was significantly greater in patients who used cannabis. Time to revision was also significantly increased in patients who used cannabis, with increased 30- and 90-day revision frequency compared with the non-cannabis group. Infection was the most common cause for revision in both groups (33.5% nonusers versus 36.6% cannabis users). Cannabis use can result in decreased implant survivorship and increased risk for revision within the 90-day global period compared with cannabis nonusers after primary TKA [30].

It has recently been reported that although opioids have been widely used for pain control following TKA, multiple level I and II studies have been published in recent years supporting the use of local infiltration analgesia and multimodal blood loss prevention approaches for improving pain control and accelerating recovery after TKA [31, 32]. In another recent report, Waldman et al. strongly recommended that institutions ensure non-opioid-based comprehensive pain management and multimodal and regional anesthesia strategies for TKA [33]. These approaches have been demonstrated to diminish opioid use, increase patient satisfaction, and shorten lengths of stay.

1.3.7 Smoking

In 2018, Bedard et al. investigated the potential impact of smoking on RTKA [34]. They found that smokers had a higher percentage of any wound complication (3.8% vs. 1.8%), deep PJI (2.5% vs. 1.0%), pneumonia (1.3% vs. 0.4%,), and reoperation (5.0% vs. 3.1%) compared with nonsmokers undergoing RTKA. A multivariate analysis identified current smokers as being at a significantly increased risk of any wound complication and deep PJI after RTKA. This study showed that smoking significantly augments the risk of PJI, wound complications, and reoperation following RTKA. The outcomes are even more exaggerated for revision procedures compared with published effects of smoking on primary TKA adverse events [34].

Rodriguez-Merchan reported that orthopedic perioperative complications of smoking include impaired wound healing, augmented PJI, and poorest TKA outcomes [35]. The adoption of smoking cessation methods such as transdermal patches, chewing gum, lozenges, inhalers, sprays, bupropion, and varenicline in the perioperative period should be advised. Perioperative smoking cessation appears to be an efficacious method to diminish postoperative complications, even if implemented as late as 4 weeks before TKA [35].

1.3.8 Metal Allergy (Nickel Sensitization)

Lionberger et al. have investigated the potential role of metal allergy sensitization in RTKA [36]. They hypothesized that nickel sensitization plays a role in the pathology of failed TKA in patients with unexplained dissatisfaction. Thirty-two patients with symptomatic TKA without obvious mechanical findings were tested prior to revision surgery. Nineteen nickel-sensitized and 13 nonsensitized patients were compared by cell counts of synovium surgical specimens for $CD4^+$ and $CD8^+$ cell lines. Patients were then revised with ceramic-coated implants. The nickel-sensitive patients showed a statistical increase in $CD4^+$ reactivity compared with $CD8^+$ reactivity. The ratio of $CD4^+/CD8^+$ T lymphocytes was 1.28 in nickel-sensitive patients versus 0.76 in the control. This study provided objective data via histological analysis in support of a nickel allergic sensitization in failed TKAs in which clinical and/or radiographic abnormalities might not be apparent [36].

Fröschen et al. have reported that the implantation of a cementless, hypoallergenic TKA might be a surgical treatment strategy in patients with evidence of allergies [37]. They reported six patients with aseptic loosening following TKA who underwent revision surgery after testing positive for benzoyl peroxide (BPO) hypersensitivity. After clarification of possible other causes of implant failure, epicutaneous testing was performed, and the implants were replaced in a two-stage procedure with cementless, diaphyseal anchoring, hypoallergenic (TiNb-coated) revision implants. Epicutaneous testing revealed a BPO allergy in all six patients and an additional nickel allergy in three of the six patients. There was no histopathological or microbiological evidence for a PJI. The clinical follow-up demonstrated a low level of pain with good function, a stable knee joint, and a proper implant position. Two implant-specific adverse events occurred: femoral stress shielding 2 years postoperatively with no further need for action and aseptic loosening of the tibial stem with the need of revision 3 years postoperatively. The regression of complaints after RTKA with cementless and nickel-free revision implants suggested allergic implant intolerance [37].

1.3.9 Preoperative Valgus Deformity

In a prognostic study (level III of evidence), Mazzotti et al. have shown that preoperative valgus deformity has twice the risk of failure compared with varus deformity after TKA [38]. A total of 2327 TKA procedures performed from 2000 to 2016 were included in the study. A total

of 640 primary TKAs with a diagnosis of valgus deformity were evaluated, with a median follow-up of 3.3 years; 1687 primary TKAs with a diagnosis of varus deformity were evaluated with a median follow-up of 2.5 years. Bi-compartmental, cemented, posterior-stabilized, fixed-bearing implants were preferred. For both diagnoses, the implant survivorship percentage was greater than 98% in the first year. However, the survival curve of the TKAs implanted for valgus deformity showed a greater slope in the first 3 years compared with the survival curve of those implanted for varus deformity. Valgus deformity had a 2.1-fold higher risk for RTKA compared with varus deformity. Infection was a major cause of implant failure in TKAs for varus deformity (9/24, 37.5%), whereas its rate was lower for valgus deformity (1/21, 4.8%) [38].

1.3.10 Hybrid vs. Standard Cemented Fixation

Gomez-Vallejo et al. compared the results of RTKA with hybrid vs. standard cemented fixation in a level III of evidence study [39]. During the period 2000–2013, RTKA was performed on 67 patients (29 cemented arthroplasty and 38 hybrid fixation). The average follow-up was 7 years (range 2–15). The main conclusion was that although the outcomes were analogous for the two groups, hybrid fixation tended to produce better outcomes than cemented fixation. In view of the risk of further loosening, these authors advised hybrid fixation [39].

1.3.11 Immediate Postoperative Mechanical Axis

In a 10-year follow-up study, Park et al. investigated whether immediate postoperative mechanical axis is associated with the revision rate of primary TKA [40]. They evaluated the association between the immediate postoperative mechanical alignment of the lower limb and the frequency of RTKA by comparing an adequate mechanical axis group (within ±3° from neutral alignment) and an outlier group (>3° deviation from neutral alignment). The main conclusion was that restoration of neutral limb alignment resulted in a lower revision percentage and higher longevity in TKA. However, there were no significant differences in clinical results between the two groups [40].

1.3.12 Physical Activity

In a prognostic study (level III of evidence), Ponzio et al. demonstrated that active patients have an elevated revision risk. The revision rate was higher for active patients (3.2%) compared with inactive patients (1.6%) at 5–10 years postoperatively. Accordingly, active patients should be carefully counseled regarding TKA to give them an understanding of its limitations and the potential risk of future revision. Active patients were defined by a Lower Extremity Activity Scale (LEAS) level of 13–18 [41].

1.4 Conclusions

Aseptic loosening, periprosthetic joint infection (PJI), and periprosthetic fracture are the most frequent causes of revision after total knee arthroplasty (TKA). Other less common causes of revision TKA (RTKA) are instability, pain, polyethylene wear, restriction of motion (arthrofibrosis), extensor mechanism insufficiency, mechanical defect, and metal allergy (nickel). Failed previous debridement, antibiotics, irrigation, and implant retention (DAIR) are related to higher failure percentages. Preoperative opioid use, younger age, obesity, and smoking are associated with early RTKA. Risk factors for RTKA are preoperative valgus deformity (valgus deformity has a 2.1-fold higher risk for RTKA compared with varus deformity), immediate abnormal postoperative mechanical axis (>3° deviation from neutral alignment), and physical activity (the revision rate is higher for active patients [3.2%] compared with inactive patients [1.6%] at 5–10 years postoperatively). Active patients are defined by a Lower Extremity Activity Scale (LEAS) level of 13–18. Smokers

have a higher percentage of any wound complication (3.8% vs. 1.8%), deep infection (2.5% vs. 1.0%), pneumonia (1.3% vs. 0.4%,), and reoperation (5.0% vs. 3.1%) compared with nonsmokers undergoing RTKA. Patients who abuse drugs are at augmented risk for RTKA. Amphetamine users have the fastest mean time to revision (691 days). At 30 days, 90 days, and 6 months postoperatively, cocaine users have the highest rate of requiring RTKA (7%, 12%, and 20%, respectively); at 1 year, it is alcohol abusers (38%). PJI is the most common cause of RTKA in all drug abuse/drug-dependent groups.

References

1. Jennings MY, Sousa PL, Abdel MP. Longevity: characteristics of a well-functioning, long-lasting total knee arthroplasty. In: Rodriguez-Merchan EC, Oussedik S, editors. Total knee arthroplasty: a comprehensive guide. Cham: Springer International Publishing Switzerland; 2015. p. 89–100.
2. Patil S, McCauley JC, Pulido P, Colwell CW Jr. How do knee implants perform past the second decade? Nineteen- to 25-year follow-up of the press-fit condylar design TKA. Clin Orthop Relat Res. 2015;473:135–40.
3. Kurz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am. 2007;89:780–5.
4. W-Dahl A, Robertsson O, Lindgren L. Surgery for knee osteoarthritis in younger patients. Acta Orthop. 2010;81:161–4.
5. Kurz SM, Lau E, Ong K, Zhao K, Kelly M, Bozic KJ. Future young patient demand for primary and revision joint replacement: national projections from 2010 to 2030. Clin Orthop Relat Res. 2009;467:2606–12.
6. Evangelopoulos DS, Ahmad SS, Krismer AM, Albers CE, Hoppe S, Kleer B, Kohl S, Ateschrang A. Periprosthetic infection: major cause of early failure of primary and revision total knee arthroplasty. J Knee Surg. 2018; https://doi.org/10.1055/s-0038-1672203.
7. Delanois RE, Mistry JB, Gwam CU, Mohamed NS, Choksi US, Mont MA. Current epidemiology of revision total knee arthroplasty in the United States. J Arthroplasty. 2017;32:2663–8.
8. Roche M, Law TY, Sultan AA, Umpierrez E, Khlopas A, Rosas S, Kurowicki J, Wang K, Mont MA. Racial disparities in revision total knee arthroplasty: analysis of 125,901 patients in National US Private Payer Database. J Racial Ethn Health Disparities. 2019;6:101. https://doi.org/10.1007/s40615-018-0504-z.
9. Choi YJ, Lee KW, Ha JK, Bae JY, Lee SK, Kim SB, Seo DK. Comparison of revision rates due to aseptic loosening between high-flex and conventional knee prostheses. Knee Surg Relat Res. 2018;30:161–6.
10. Postler A, Lützner C, Beyer F, Tille E, Lützner J. Analysis of total knee arthroplasty revision causes. BMC Musculoskelet Disord. 2018;19:55.
11. Rodriguez-Merchan EC. Review article: risk factors of infection following total knee arthroplasty. J Orthop Surg (Hong Kong). 2012;20:236–8.
12. Encinas-Ullan CA, Rodriguez-Merchan EC. Arthroscopic treatment of total knee arthroplasty complications. EFORT Open Rev. 2019;4:33–43.
13. Liddle AD, Rodriguez-Merchan EC. Periprosthetic fractures. In: Rodriguez-Merchan EC, Oussedik S, editors. Total knee arthroplasty. A comprehensive guide. Cham: Springer International Publishing; 2015. p. 219–28.
14. Rodriguez-Merchan EC, Gomez-Cardero P, Martinez-Lloreda A. Revision knee arthroplasty with a rotating-hinge design in elderly patients with instability following total knee arthroplasty. J Clin Orthop Trauma. 2015;6:19–23.
15. Rodriguez-Merchan EC. Instability following total knee arthroplasty. HSS J. 2011;7:273–8.
16. Rodriguez-Merchan EC. Revision total knee arthroplasty: surgical technique in dealing with instability. In: Rodriguez-Merchan EC, Oussedik S, editors. Total knee arthroplasty. A comprehensive guide. Cham: Springer International Publishing; 2015. p. 259–66.
17. Rodriguez-Merchan EC. Total knee arthroplasty using hinge joints: indications and results. EFORT Open Rev. 2019;4:121–32.
18. Rodriguez-Merchan EC. Liddle AD. Epidemiology of the infected total knee arthroplasty: incidence, causes, and the burden of disease. In: Rodriguez-Merchan EC, Oussedik S, editors. The infected total knee arthroplasty. Cham: Springer International Publishing AG; 2018. p. 1–9.
19. Rhee C, Lethbridge L, Richardson G, Dunbar M. Risk factors for infection, revision, death, blood transfusion and longer hospital stay 3 months and 1 year after primary total hip or knee arthroplasty. Can J Surg. 2018;61:165–76.
20. Matar HE, Stritch P, Emms N. Higher failure rate of two-stage revision for infected knee arthroplasties in significantly compromised (host-C) patients. Knee Surg Sports Traumatol Arthrosc. 2019;27:2206. https://doi.org/10.1007/s00167-018-5051-y.
21. Fu J, Ni M, Li H, Li X, Chai W, Zhou Y, Hao L, Chen J. The proper timing of second-stage revision in treating periprosthetic knee infection: reliable indicators and risk factors. J Orthop Surg Res. 2018;13:214.
22. Rajgopal A, Panda I, Rao A, Dahiya V, Gupta H. Does prior failed debridement compromise the outcome of subsequent two-stage revision done for periprosthetic joint infection following total knee arthroplasty? J Arthroplasty. 2018;33:2588–94.
23. Rodriguez-Merchan EC. The influence of obesity on the outcome of TKR: can the impact of obesity be

justified from the viewpoint of the overall health care system? HSS J. 2014;10:167–70.
24. Tohidi M, Brogly SB, Lajkosz K, Grant HJ, VanDenKerkhof EG, Campbell AR. Ten-year mortality and revision after total knee arthroplasty in morbidly obese patients. J Arthroplasty. 2018;33:2518–23.
25. Tsai YS, Kung PT, Ku MC, Wang YH, Tsai WC. Effects of pay for performance on risk incidence of infection and of revision after total knee arthroplasty in type 2 diabetic patients: a nationwide matched cohort study. PLoS One. 2018;13:e0206797.
26. Gu A, Wei C, Maybee CM, Sobrio SA, Abdel MP, Sculco PK. The impact of chronic obstructive pulmonary disease on postoperative outcomes in patients undergoing revision total knee arthroplasty. J Arthroplasty. 2018;33:2956–60.
27. Roche M, Law TY, Sodhi N, Rosas S, Kurowicki J, Disla S, Wang K, Mont MA. Incidence of drug abuse in revision total knee arthroplasty population. J Knee Surg. 2018;31:928–33.
28. Bedard NA, DeMik DE, Dowdle SB, Owens JM, Liu SS, Callaghan JJ. Preoperative opioid use and its association with early revision of total knee arthroplasty. J Arthroplasty. 2018;33:3520–3.
29. Weick J, Bawa H, Dirschl DR, Luu HH. Preoperative opioid use is associated with higher readmission and revision rates in total knee and total hip arthroplasty. J Bone Joint Surg Am. 2018;100:1171–6.
30. Law TY, Kurowicki J, Rosas S, Sabeh K, Summers S, Hubbard Z, Roche M. Cannabis use increases risk for revision after total knee arthroplasty. J Long Term Eff Med Implants. 2018;28:125–30.
31. Rodriguez-Merchan EC. Single local infiltration analgesia (LIA) aids early pain management after total knee replacement (TKR): an evidence-based review and commentary. HSS J. 2018;14:47–9.
32. Rodriguez-Merchan EC, Vaquero-Picado A, Ruiz-Perez JS. Opioid-free total knee arthroplasty? HSS J. 2019;15:209–11.
33. Waldman S, Cornell CN, Shapiro LA, Albert TJ, Schairer W, Rodriguez-Merchan EC, et al. Consensus statement: toward opioid-free arthroplasty: a leadership forum. HSS J. 2019;15:4–7.
34. Bedard NA, Dowdle SB, Wilkinson BG, Duchman KR, Gao Y, Callaghan JJ. What is the impact of smoking on revision total knee arthroplasty? J Arthroplasty. 2018;33(7S):S172–6.
35. Rodriguez-Merchan EC. The importance of smoking in orthopedic surgery. Hosp Pract (1995). 2018;46:175–82.
36. Lionberger DR, Samorajski J, Wilson CD, Rivera A. What role does metal allergy sensitization play in total knee arthroplasty revision? J Exp Orthop. 2018;5:30.
37. Fröschen FS, Gravius N, Lau JF, Randau TM, Kaup E, Friedrich MJ, Gravius S. A case series of cementless revision total knee arthroplasty in patients with benzoyl peroxide allergy. Int Orthop. 2018; https://doi.org/10.1007/s00264-018-4273-4.
38. Mazzotti A, Perna F, Golinelli D, Quattrini I, Stea S, Bordini B, Faldini C. Preoperative valgus deformity has twice the risk of failure as compared to varus deformity after total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc. 2018; https://doi.org/10.1007/s00167-018-5331-6.
39. Gomez-Vallejo J, Albareda-Albareda J, Seral-Garcia B, Blanco-Rubio N, Ezquerra-Herrando L. Revision total knee arthroplasty: hybrid vs standard cemented fixation. J Orthop Traumatol. 2018;19:9.
40. Park JK, Seon JK, Cho KJ, Lee NH, Song EK. Is immediate postoperative mechanical axis associated with the revision rate of primary total knee arthroplasty? A 10-year follow-up study. Clin Orthop Surg. 2018;10:167–73.
41. Ponzio DY, Chiu YF, Salvatore A, Lee YY, Lyman S, Windsor RE. An analysis of the influence of physical activity level on total knee arthroplasty expectations, satisfaction, and outcomes: increased revision in active patients at five to ten years. J Bone Joint Surg Am. 2018;100:1539–48.

2 Revision Total Knee Arthroplasty: Surgical Technique

Carlos A. Encinas-Ullán, Primitivo Gómez-Cardero, and E. Carlos Rodríguez-Merchán

2.1 Introduction

The number of revisions of total knee arthroplasty (RTKA) cases is increasing. Moreover, we are seeing increasingly complex cases, which explains why RTKA is associated with a high percentage of complications and poor results. We must understand the underlying problem before we can fix the implant. Exploratory surgery in RTKA is contraindicated. RTKA is a two-step process: first, implant removal and second, joint reconstruction. However, the first process can compromise the second. The total time for revision should not exceed 60 min for component removal, 60 min for joint reconstruction, and 30 min for adequate wound closure to minimize the risk of infection.

2.2 Optimal Exposure

It is important to plan and use the following stepwise approach (Fig. 2.1).

2.2.1 Skin Incision

We must use the previous incision, avoiding close parallel incisions and skin bridges of >7 cm and an angle >60° to the old incision to avoid skin necrosis [1]. If there are multiple surgical scars, we will select the most recent scar, the one with the most lateral and vertical orientation (given the vascularization of the skin originates in the medial part of the knee). If there are fistulas, they should be removed together with the skin incision and all the way to the joint capsule.

If there are wide and immobile scars, a plastic surgery consultation is recommended. It is also important to note that the cutaneous blood supply travels from deep to superficial. Hence, a full thickness skin flap must be created and medial dissection performed in a subfascial plane, avoiding large lateral flaps. We use atraumatic retractors and avoid excessive skin retraction. Polyethylene extraction together with hyperflexion and external rotation of the knee also will decrease tension in the soft tissues. Additional skin techniques can be used with soft tissue expansion prior to RTKA [2].

2.2.2 Arthrotomy

We typically start with a long, standard medial parapatellar approach. A subvastus approach in RTKA is not recommended due to the difficulty of moving the patella laterally. After the arthrot-

C. A. Encinas-Ullán · P. Gómez-Cardero
E. C. Rodríguez-Merchán (✉)
Department of Orthopedic Surgery,
"La Paz" University Hospital, Madrid, Spain

E. C. Rodríguez-Merchán (ed.), *Revision Total Joint Arthroplasty*,
https://doi.org/10.1007/978-3-030-24773-7_2

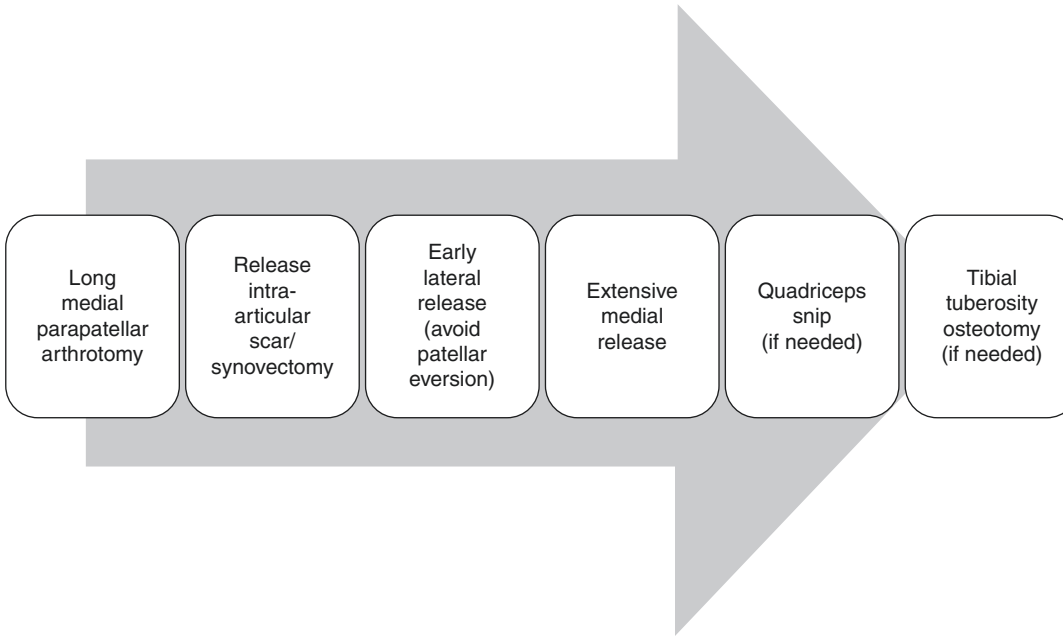

Fig. 2.1 Optimal exposure algorithm in revision total knee arthroplasty (RTKA)

omy, we perform a release of the intra-articular scar and synovectomy to increase knee flexion. We release the suprapatellar pouch and the medial and lateral gutters. We also release peripatellar adhesions and the upper edge of the anterior tibial tuberosity (TT). If there is significant tension in the patellar tendon, we perform an early lateral release from the inside out from the lateral aspect of the patella to the lateral aspect of the patella tendon to the TT. Patellar subluxation is usually adequate, and eversion is not needed; a surgical pitfall is to place a fixation pin in the medial insertion of the patellar tendon to prevent lateral avulsion. We perform an extensile medial tibial subperiosteal release (superficial medial collateral ligament, pes anserinus, posteromedial capsule, and semimembranosus insertion) to allow external rotation of the tibia and lateralization of the TT. If the extensor mechanism is adhered to the distal femur, a release is performed with complete elevation of the quadriceps mechanism. Avulsion of the patellar tendon can compromise knee function drastically and must be avoided; therefore, if tension persists, we will consider more extensile approaches to ensure adequate exposure.

2.2.3 Extensile Exposures

If the mobility of the knee is 70° or less, an extensile exposure is necessary. There are three classical techniques: proximal V-Y quadricepsplasty, quadriceps snip, and TT osteotomy (at the distal level).

The V-Y quadricepsplasty technique consists of sectioning the quadriceps tendon in an inverted V. Wound closure will be done in an inverted Y to lengthen the tendon and allow better flexion. Another alternative is the modified Insall technique, continuing the medial parapatellar incision of the quadriceps tendon in a 45° direction toward the superolateral angle of the patella. Patients often have an extensor lag that affects quadriceps strength and changes the postoperative rehabilitation protocol. There is a risk of avascular necrosis of the patella if we injure the superior lateral geniculate artery. Our preference is the quadriceps snip technique because it is quick, easy, and there is no need to modify the postoperative rehabilitation protocol. It consists of extending the medial parapatellar approach through the quadriceps tendon with an angle of 45° toward the vastus lateralis. It is performed

from distal-medial to proximal-lateral. It is an easy technique and with similar results to the classical medial arthrotomy in terms of strength and postoperative range of motion [3].

TT osteotomy is another alternative in RTKA. We use it when adequate exposure is not achieved after a quadriceps snip, if access to the tibial intramedullary canal is needed to remove a long-stemmed cemented tibial component, or when there is arthrofibrosis or patella baja. Typically, the bone fragment must be long (at least 6 cm is recommended) with the coronal osteotomy made from the medial side. If it is very long, there is a risk of tibial diaphysis fracture, and if it is short, we may have fixation problems. Proximally, the thickness should be approximately 1 cm for exposure of a stiff knee tapering distally to approximately 5 mm; if performed to aid in removal of a long-stemmed cemented tibial component, it should be thicker to allow better access to the tibial canal. It can be performed with an osteotome or oscillating saw, leaving a lateral periosteal and soft tissue hinge. To avoid the risk of diaphyseal fracture, we can perform a distal osteotomy, and to avoid proximal migration of the fragment, we can perform a proximal osteotomy to create steps of about 5 mm of tibial bone between the osteotomy and the proximal tibia. The fragment can be fixed with wires (three small drill holes are made in the lateral aspect of the bony fragment and three holes in the medial tibia approximately 1 cm posterior to the edge of the osteotomy and slightly distal) or at least two screws (to avoid possible fracture of the osteotomy fragment and placed into the tibial cortex in a divergent manner to avoid the tibial stem).

The tibial stems should bypass the distal part of the osteotomy by at least 2 cortical diameters to reduce the risk of fracture.

Postoperatively, if rigid fixation is achieved, we will allow full weight bearing and unrestricted mobility, avoiding active extension and straight leg raises. Other authors prefer to protect the repair with a hinged knee brace until the osteotomy heals (Fig. 2.2).

The following additional extensile exposures techniques can be used:

- Extensive femoral peel, complete subperiosteal peel of the femur, including origins of collateral ligaments.
- Medial epicondylar osteotomy.
- "Banana peel" patellar tendon off TT, leaving a lateral soft tissue hinge.

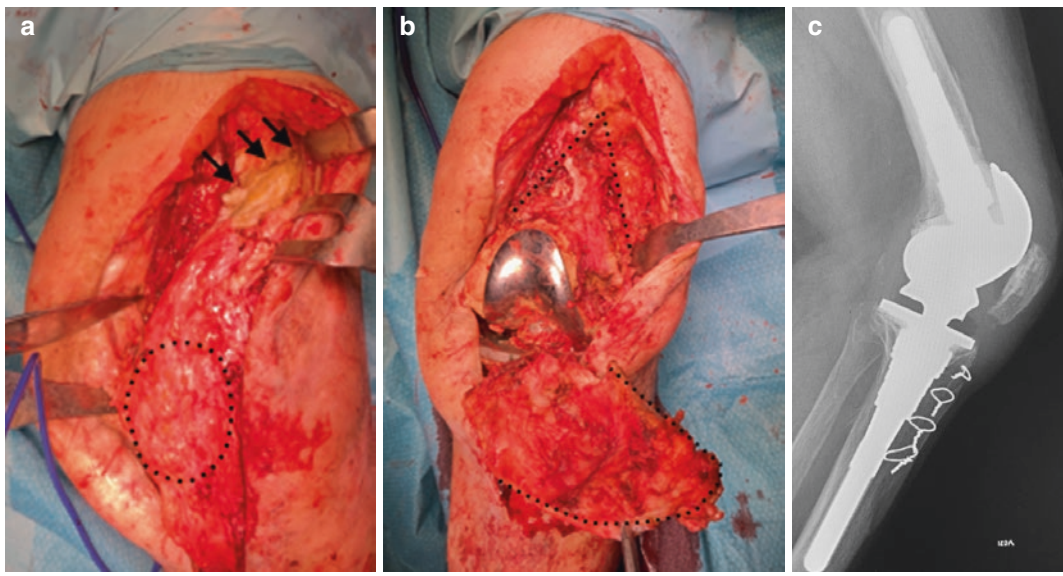

Fig. 2.2 (**a**) V-Y quadricepsplasty technique; (**b**) quadriceps snip technique; (**c**) lateral radiographs showing reduction of the tibial tuberosity (TT) osteotomy with wire fixation of the osteotomy fragment

2.3 Component Removal

The position, rotation, and alignment of the components should be assessed before component removal, with any deficiencies addressed and improved afterward. Component removal should be preplanned in a systematic fashion to prevent complications.

The objective is implant removal with bone stock preservation (preserving the intact cortical rims), avoiding fractures or diaphyseal perforation and soft tissue (ligaments, tendons, and capsule) injuries.

Component removal is a critical step in a successful RTKA. We recommend the following sequential approach: polyethylene removal; femoral component removal, creating additional space for removal of the tibial component; and patellar component removal if necessary (Table 2.1) [4].

The technique to remove a TKA is more invasive when it is uncemented. The removal of constrained prostheses with intramedullary stems is more difficult than the removal of condylar implants. In general, both are more invasive for the femur than for the tibia. We must avoid damaging the underlying bone during component extraction.

2.3.1 Polyethylene

The surgeon must know which implant is in place and also its polyethylene block system, because manufacturer-specific tools for extraction may be required.

Table 2.1 Instruments required for interface disruption in revision total knee arthroplasty (RTKA)

Hand tools	Power tools
Osteotomes set (flexible and rigid, straight, curved, and angled)	Oscillating saw (section polyethylene)
Gigli saw	High speed burrs (section metal, intramedullary cement)
Disimpaction punches	Drills and trephines
Component extractors (universal and prosthesis specific)	

The polyethylene tibial insert is removed first to facilitate exposure of the TKA and the knee flexion. The removal of the polyethylene insert is usually easy and can be performed with the tip of a standard Hohmann retractor inserted between the polyethylene and the tibial component and pulling the polyethylene forward and upward.

To remove a monobloc or an all-polyethylene tibial component, it is separated from the tibial surface by sectioning the pegs or the stem.

2.3.2 Cemented Femoral Components

Cemented femoral components are rarely loose; aggressive maneuvers to remove well-fixed implants should be avoided due to the risk of iatrogenic femoral shaft fracture, condyle fracture, or bony avulsion.

We recommended circumferentially releasing the periphery of the distal femur to achieve adequate exposure and then proceed to remove the component. Initially, we divide the peripheral prothesis-cement interface with rigid osteotomes or an oscillating saw, always progressing to the central portions of the prothesis-cement interface parallel to the femoral component to avoid cutting into the bone. First, the anterior femoral component from medial to lateral and proximal to distal, later the anterior chamfer and the distal femur; an alternative is to use a Gigli saw inserted from the top of the trochlea and advanced distally to the box or the pegs. Then continue to the posterior chamfer and posterior condyle, taking care not to damage the collateral ligaments and soft tissues. Angled osteotomes are used to work from "inside out" in the femoral box.

For the proper extraction, we can hit the axis of the implant with a hammer and an impactor in the proximal part of the component. Alternatively, we can use a manufacturer-specific extractor (Fig. 2.3). The femoral component's undersurface should be inspected to assess the amount of iatrogenic damage (Fig. 2.4). Finally, we remove the cement under direct vision and divide it into small sections.

Fig. 2.3 Removal of the femoral component using direct impaction in the proximal part (**a**). Alternatively, a manufacturer-specific extractor may be used (**b**)

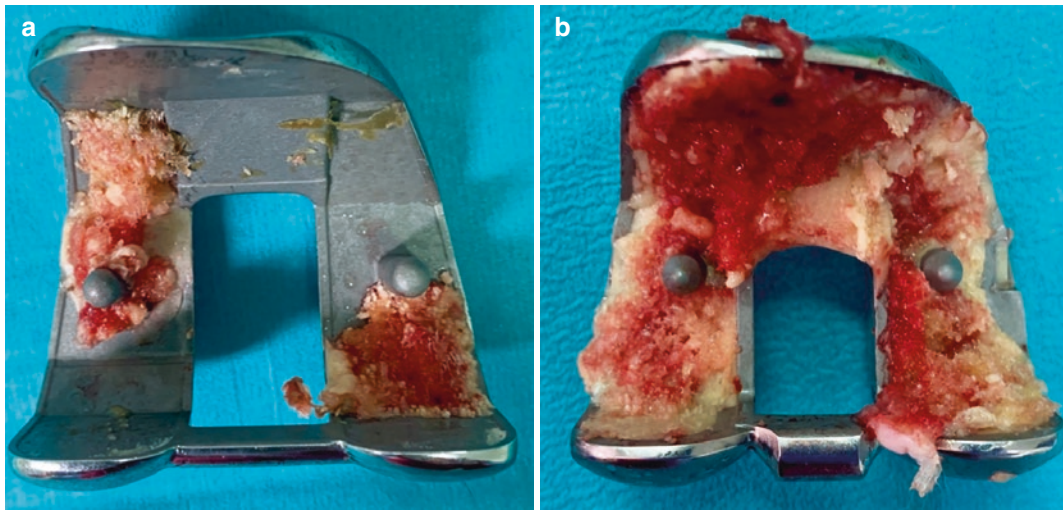

Fig. 2.4 The femoral component's undersurface is inspected to assess the amount of iatrogenic damage: (**a**) undersurface showing minimal bone loss; (**b**) undersurface showing significant bone loss

2.3.3 Cemented Tibial Components

The tibial component is next. Tibial exposure is improved by moving it anteriorly, externally rotating it and releasing of the semimembranosus and the posterior capsule. For safe removal, 360° exposure of the tibial component is necessary. Cemented tibial components are removed by using the same principles as the femoral component; osteotomes or an oscillating saw are used to cut beneath and parallel to the component, first on the anteromedial area and then on the posteromedial area, which is the most difficult. Then we advance around the keel or pegs. Later, we

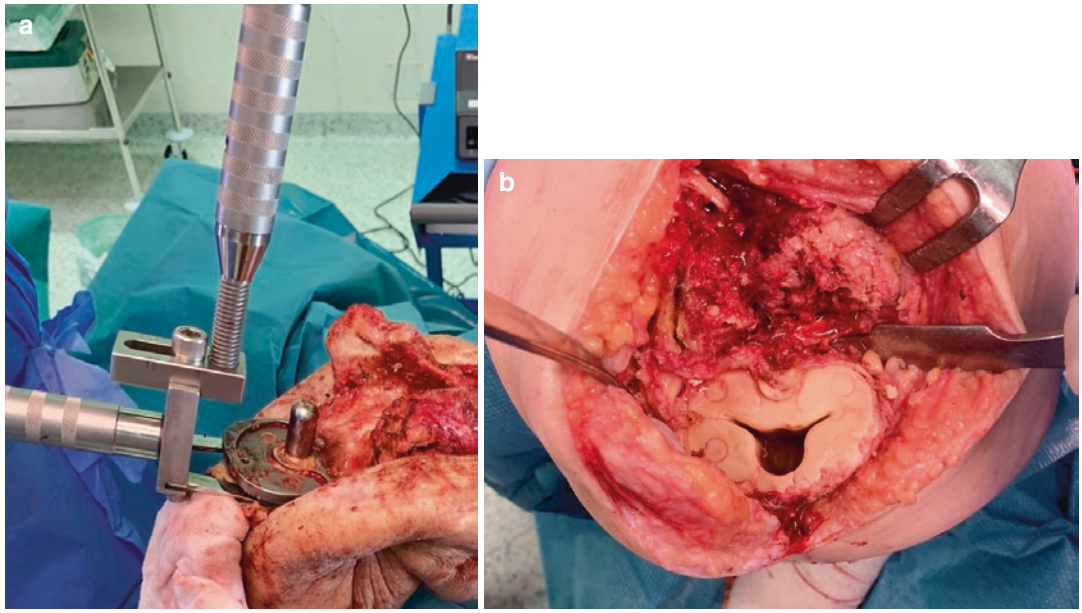

Fig. 2.5 (**a**) Use a manufacturer-specific extractor to lift the baseplate off the tibial bone. Alternatively, try direct impaction under the anteromedial area of the implant, or use the "stacked osteotomes" technique. Finally, we remove the cement under direct vision (**b**)

continue to the lateral side, which is more dangerous, taking care not to damage the patellar tendon. We must be careful in the posterolateral area to avoid bone stock loss during the removal. A Gigli saw can be used in the posterolateral area.

To achieve an adequate extraction, we can hit the anteromedial area of the implant with a hammer and an impactor. Alternatively, we can use the "stacked osteotomes" technique, which consists of inserting osteotomes, one on top of another, between the tibial bone and the component to gently lift. Also, we can use a manufacturer-specific extractor (Fig. 2.5a). The tibial component's undersurface must be inspected to assess the amount of iatrogenic damage. Finally, we remove the cement under direct vision, dividing it into small fragments (Fig. 2.5b).

2.3.4 Press-Fit Components

Removal of a porous-coated prosthesis can be difficult, especially when it has pegs designed for bone ingrowth. If the component cannot be removed with a specific or universal extractor, the union between the peg and the bone must be loosened. We can make a window in the femur (in the lateral walls of the intercondylar notch or in the condyles) and in the tibia (at a point as close as possible to the peg). Alternatively, we can use a microsagittal saw parallel to the tibial component to separate the metal backed from the pegs. It can be done freehand or using the tibial resection block with an extramedullary guide (maintaining the direction during the cut of the pegs). During metal cutting, the rest of the knee should be covered with compresses to prevent the introduction of metal debris, which could cause metallosis and/or synovitis.

2.3.5 Patellar Component

Patellar revision can be avoided if the patellar component is undamaged, well-fixed, well-positioned, and compatible with the revision implant and in cases of aseptic RTKA. Appropriate patellar tracking is paramount to a successful revision. The majority of patellar components are

cemented all-polyethylene implants; we use the oscillating saw to cut between the cement and the component interface and section the peg-patellar component junction. The pegs and residual cement are then removed with a high-speed burr or a drill bit. Metal-backed and cementless components are more difficult to remove. A high-speed diamond-edged saw is then necessary. In order not to fracture the patella, lever movement of the component with osteotomes should be avoided.

2.3.6 Long-Stemmed Components

More and more often, revision prostheses are removed in which long stems have been used to achieve stability. We have learned the techniques of extraction of the stems from the extraction of femoral stems during revision total hip prostheses. In cases with a well-fixed stem component, we must make a window to liberate the stem using straight or curved osteotomes. At level of the femur, we create an anterior window using an oscillating saw or the combination of drill hole and an osteotome; the window must be 10–15 mm wide and almost as long as the stem. At the tibia, we will make a TT osteotomy. The window is then fixed with wires or metallic cables. To prevent a stress riser, it is necessary to bypass the osteotomy with a stemmed revision implant in which the stem extends beyond the window by at least 2 cortical diameters.

2.4 Joint Reconstruction

The goals of RTKA are the following: achieve good alignment, restore the joint stability, and achieve a well-balanced revision construct with optimal fixation and minimized constraint.

2.4.1 Balancing

The adjustments made on the femoral side can affect the knee in flexion or extension, whereas adjustments on the tibial side will affect both. Reconstruction is performed using a three-step method: (1) recreate the flat tibial surface, (2) recreate the femur and rebuild the flexion space, and (3) rebuild the extension space [5].

2.4.1.1 Recreate the Tibia

The first step is to build a tibial base to facilitate gap balancing, because any change on the tibial side affects the flexion and extension gaps. We must create a flat surface perpendicular to the mechanical axis. The flat tibial surface should be close to the original height of the tibia. Often, only one condyle is intact, and it will be used for referencing. Treatment of tibia bone loss depends on its severity and consists of cement, metal augmentation, modular cones, structural allograft, and proximal tibia replacement. To ensure the tibial component is in the proper rotation, we will use the TT and the anteromedial aspect of the tibia as reference points.

2.4.1.2 Recreate the Femur

The flexion gap should be evaluated. Femoral component sizing influences the flexion space by restoring the anteroposterior (AP) dimensions and the posterior condylar offset of the femur. Assess the femoral size from previous procedures or use the opposite side as a template. Posterior bone loss occurs almost always, so templating intraoperatively runs the risk of undersizing the femoral component. The epicondylar width of the femur also helps us select the appropriate femoral size. If we select an excessively small femoral component, there will be a failure to restore the posterior femoral offset, and it will compromise flexion stability. In general, in RTKA there is an asymmetric flexion gap, so an oversized femoral component can be used to balance the knee. Correct rotation of the femoral component is important for knee kinematics and patellar tracking. We determine the rotation with the transepicondylar axis. Generally, there is bone loss in the posterolateral condyle that requires augmentation to achieve correct rotation of the femoral component. In case of severe bone loss affecting the epicondyle, the tibial platform is used as a reference point for the rotation of the femoral component with the knee at 90° flexion.

2.4.1.3 Rebuild the Extension Gap

Next, the knee should be brought to full extension to evaluate the extension gap. The distal femur position is key to restoring the distance from the joint line, distally and posteriorly. The distance from the epicondyles to the posterior joint line is similar to that of the distal joint line and is useful to confirm the correct size of the femoral component. It is important to restore the natural joint line in revision surgery, because the joint line is always more distal than it first appears.

There are various landmarks that can be used intraoperatively to assess whether the distal joint line has been restored: a prior meniscal scar, an average of 15 mm proximal to the fibular head, 25 mm from the lateral epicondyle, and 30 mm from the medial epicondyle and 32 mm proximal to the TT.

Elevation of the joint line occurs when the bone lost from the distal femur is not reconstructed and the defect is addressed by thickening the tibial insert. Use a thicker polyethylene than in primary TKA only if you have removed more bone from the tibia; in most cases, the polyethylene thickness should be between 10 and 15 mm. Polyethylene >15 mm correlates significantly with joint line elevation, worsens the clinical outcome, and reminds us that thicker distal femoral augments, instead of thicker polyethylene inserts, should be used to restore the defects and the joint line [6]. Flexion and extension gaps must be equal and symmetric. We must release tight structures in the concavity.

2.4.2 Management of Bone Loss

Bone loss is always greater than the preoperative radiographs indicate [7]; multidetector computed tomography (CT) scans provide the most accuracy for assessing the grade of bone loss. The classification of bone loss should be performed intraoperatively after component removal (Fig. 2.6).

Bone defects can be classified according to the following characteristics:

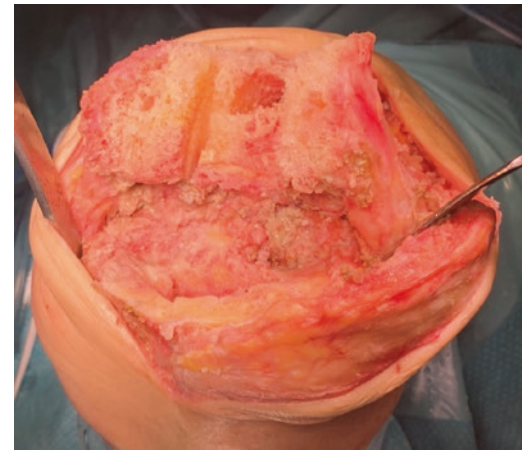

Fig. 2.6 Bone defects are evident after component removal

- Size: depth (<5 mm, 5–10 mm, >10 mm), percentage of condylar/plateau deficiency, depth relative to femoral epicondyle/tibial tubercle
- Location: central/peripheral, contained/uncontained
- Geometry: symmetric/asymmetric, "ice cream cone"/"funnel"

The Anderson Orthopedic Research Institute (AORI) bone defect classification is the most practical and commonly used system. AORI establishes three types of bone defects for the femur (F1, F2, F3) and tibia (T1, T2, T3); each type is subdivided into "A" for one condyle or one side of the tibial plateau involved and "B" for bicondylar or total plateau involvement (Fig. 2.7) [7]. Type 1 presents an intact cortical bone with minor metaphyseal bone defects (small, cavitary or contained defects <5 mm); this type of bone defect will not compromise the stability of a revision prosthetic component. They are usually managed using cement, cement, and screws or morselized allo-/autograft. Type 2 presents a loss of cortical bone with damaged metaphyseal bone that needs to be filled to restore the joint line. Type 3 is deficient metaphyseal bone, with serious bone loss that involves a major portion of a condyle or a tuberosity, causing stability disorders due to the associated ligament injury (Table 2.2).

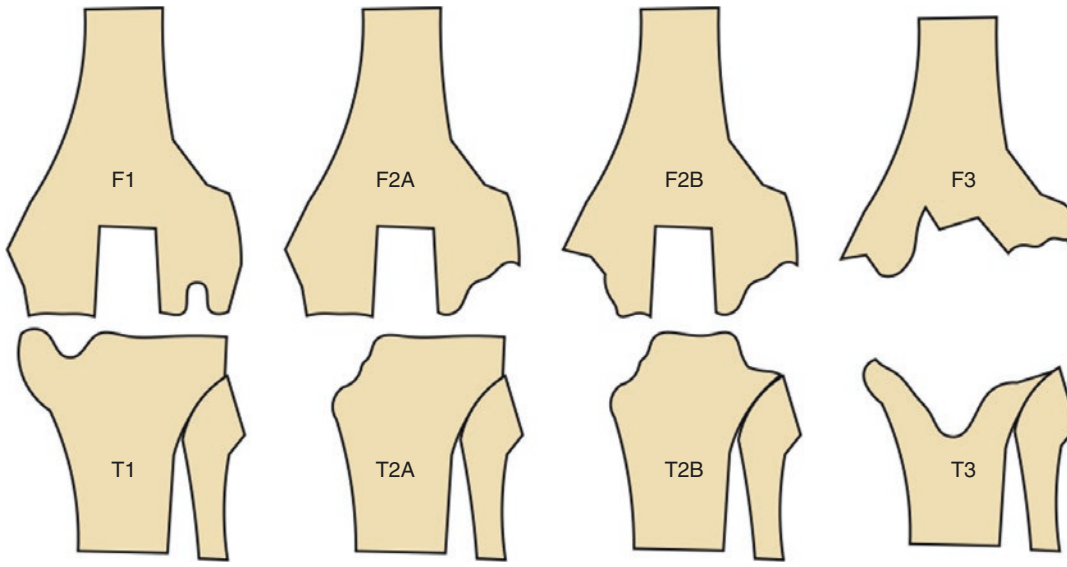

Fig 2.7 Anderson Orthopedic Research Institute (AORI) classification of bone defects

Table 2.2 Management of bone defects in revision total knee arthroplasty (RTKA) according to their type

Type 1	Types 2 and 3
Cementation ± screw	Modular metal augmentation Porous titanium metaphyseal sleeves, porous tantalum metaphyseal cones
Bone grafting: autologous, allogenic, impactation	Structural bone allograft
	Megaprosthesis/customized prosthesis

Cementation is an inexpensive and easily performed technique. The use of cement, either alone or in combination with screws, is recommended for small bone defects such as AORI type 1. First, we perform a meticulous debridement of all fibrous tissue, which impedes adequate interdigitation of the cement and creates suboptimal fixation. Later we roughen the sclerotic bone surfaces with a small drill or a burr. Convert inclined surfaces into step-shaped surfaces to minimize shear and stabilize the cement. Defects less than 5 mm in depth may be filled with cement alone. If the defects are larger, titanium screws are recommended to ensure there is no contact between the screw head and the prosthesis. This cementation technique is not recommended for larger defects due to the risk of thermal necrosis and loosening.

Modular metal augmentation is a primary option for the reconstruction because of its extensive modularity, quick and easy use, minimal resection, and ready availability. All RTKA systems include modular metal augmentation systems and have alignment and cutting guides to prepare the bone. Metal augmentation is a preshaped system with various sizes and thicknesses; it generally has been recommended only for small (≤5 mm) to medium (≤10 mm) uncontained bone defects (AORI type 2 or 3 defects). The use of metal augments requires a cutting guide with specific instruments on intramedullary guides. They are wedges or rectangular blocks in the tibia. Our preference is to remove a bit more bone and convert a wedge-shaped defect into a rectangular-shaped one and to use rectangular blocks, which are biomechanically stable and rigid. We use the intramedullary guide to align the tibial cut perpendicular to the mechanical axis and reset 1–2 mm of bone and carve the exact size and shape of the augment. It is also

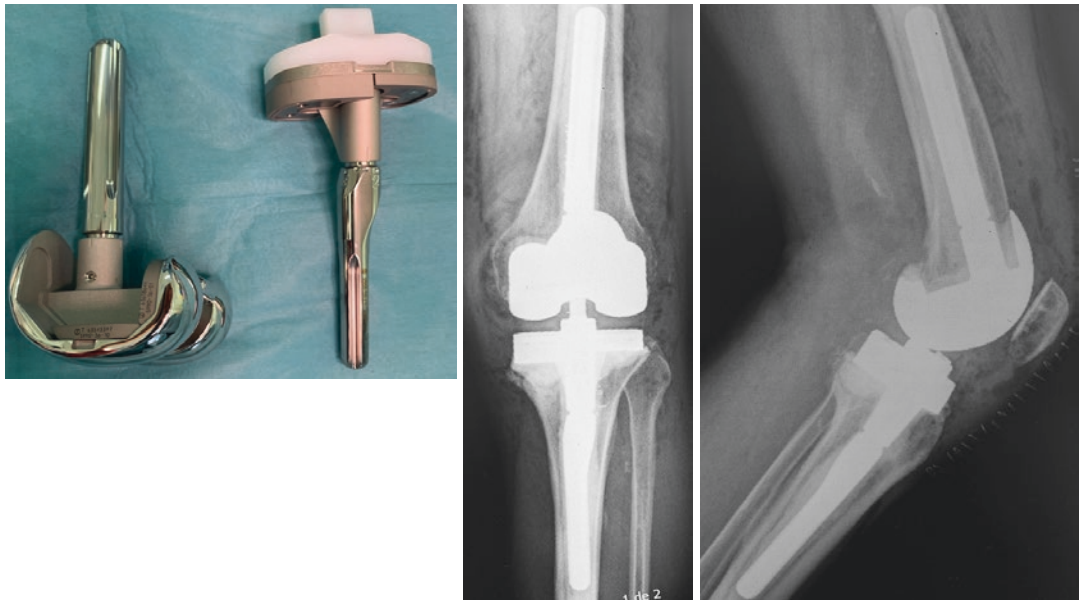

Fig. 2.8 Distal and posterior femur and proximal tibia modular metal augmentation

important to determine the proper rotation of the tibial components, which is usually aligned with the medial third of the tibial tubercle so that the sagittal cut allows the augmentation block to sit in the correct rotation. Metal augments are fixed to the prosthetic components with screws or cement. These metal augments sit in healthy bone and provide good stability to the implant with the correct transmission of pressure. Metal augments do have a risk of fretting, radiolucent lines and corrosion (Fig. 2.8).

Bone grafting is an option; cancellous or structural bone grafts have certain problems such as nonunion, delayed union, late resorption, deep infection, a risk of disease transmission, graft fracture, and size and shape mismatches. Added time is required to make the graft. The use of allografts in revision TKA has unpredictable results.

In order to avoid these disadvantages in cases of major metaphyseal damage and loss of support (tibial and femoral bone defects of AORI type 2B and 3), the porous-coated sleeves and trabecular metal cones [8] are an alternative to megaprosthesis/customized prosthesis or structural bone allograft. Studies of longer duration are needed to ascertain the survival rate of these implants.

Metaphyseal titanium tapered sleeves require sequential broaching and are implanted using the "press-fit" system. They allow a physiological load transfer and facilitate bone ingrowth for integrated components, achieving stable fixation [9] (Fig. 2.9).

Porous tantalum structural cones are a relatively new indication. There are various shapes and sizes. The porous tantalum cone is carefully impacted into the tibial or femoral metaphysis with size-specific impactors. Tibial cones reinforce the cortical rim and provide good support for the implant; additional augments can restore the alignment, and it is possible to add impactation bone grafts to interface defects. Femoral cones re-establish the metaphyseal bone, and additional femoral augments can restore the distal joint line and posterior condyles (Fig. 2.10). The rotation of the porous metal cone is independent of the final rotation of the tibial and femoral components.

The tibial or femoral component is cemented to the cone, and a stem is attached to the intact diaphyseal bone, either with or without cement or uncemented. Clinical studies on porous tantalum structural cones have shown a low rate of aseptic loosening, intraoperative fractures, and infection

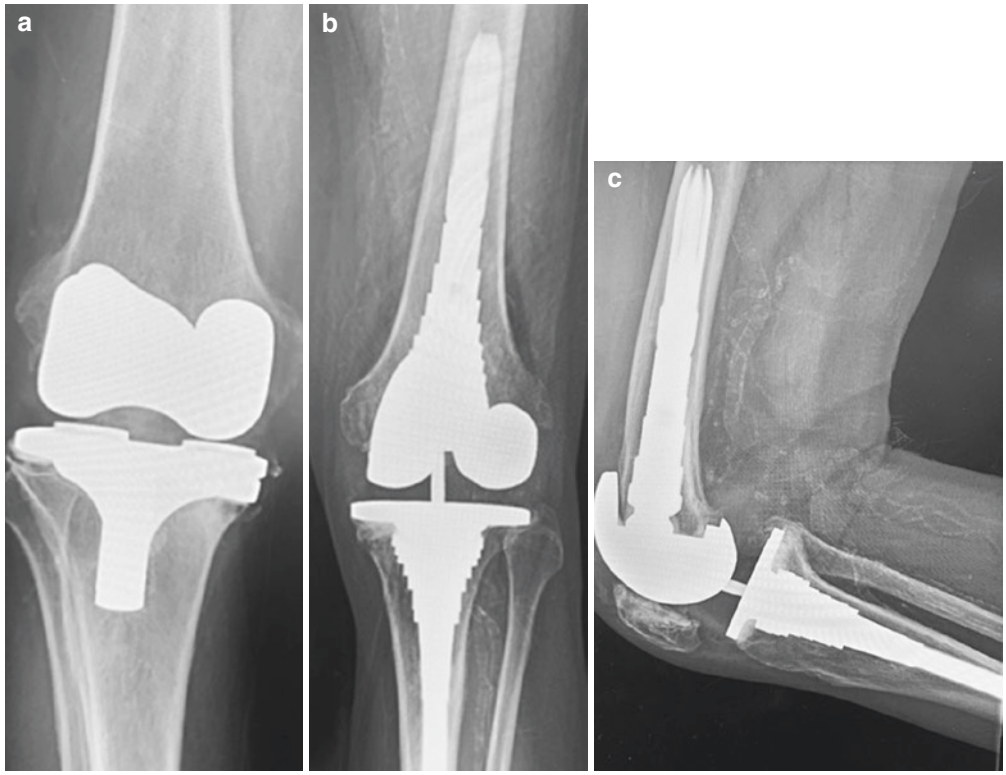

Fig. 2.9 (**a**) Preoperative anteroposterior (AP) radiograph showing a type IIA Anderson Orthopedic Research Institute (AORI) tibial defect; postoperative AP (**b**) and lateral (**c**) radiograph showing a cementless metaphyseal sleeve and stem construct

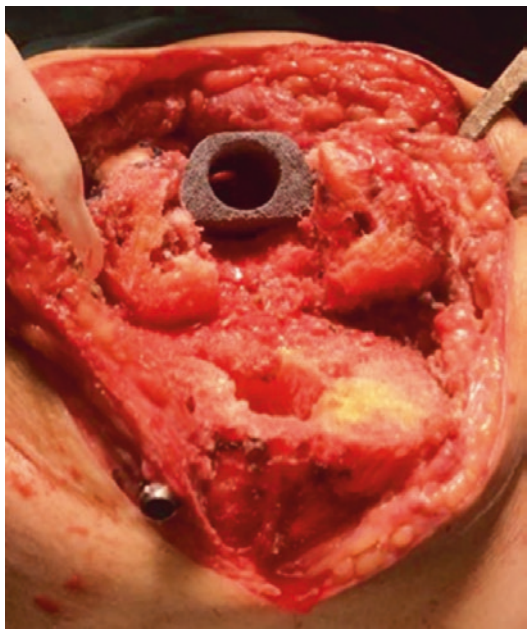

Fig. 2.10 Press-fit impaction of a femoral trabecular metal cone

rates, with an optimal overall survival rate; however, they are difficult to remove, and there is a risk of fracture of the host bone [10].

Megaprosthesis or customized prostheses are an exceptional indication for the management of complex bone defects in RTKA (uncontained extra-articular bone loss). However, these implants are expensive, not versatile, take several weeks to manufacture, and have a risk of short-term mechanical complications and infection (Fig. 2.11).

2.4.3 Fixation

The distal femur and proximal tibia can be divided into three anatomical zones in which fixation can be achieved: zone 1, the joint surface or epiphysis; zone 2, the metaphysis; and zone 3, the diaphysis [11]. Morgan-Jones et al. suggest that fixation is needed in two or more zones and

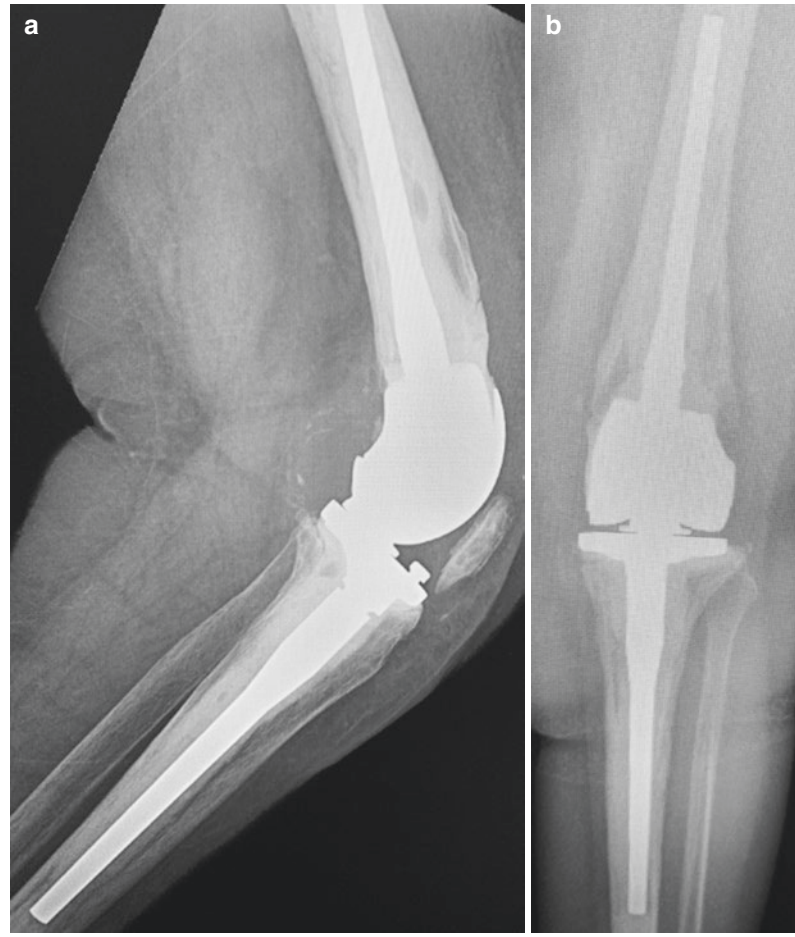

Fig. 2.11 Megaprostheses: (**a**) Lateral view; (**b**) anteroposterior view

emphasize the importance of preoperative planning and implant selection [11].

ZONE 1: The surface is often missing in revision and can be augmented with cement, bone grafts, or metal augments. Where augmentation is required, it is necessary to achieve fixation in at least one other zone. Zone 1 fixation can only be reliably achieved with cement.

ZONE 2: The metaphysis is often damaged or sclerotic. Sclerotic bone is not good for cement fixation. Metaphyseal fixation can be achieved using porous-coated sleeves and trabecular metal cones in this zone. The advent of metaphyseal fixation allows fixation closer to articulation and facilitates restoration of the joint line and greater control of rotation alignment of the components. Primary axial or rotational stability is achieved, and a long stem is not needed.

ZONE 3. This zone is the diaphysis. Fixation in zone 3 can be achieved with intramedullary stems. The optimal length and thickness of stems remain poorly defined. Stems may be cemented or uncemented. Offset stems allow better alignment of the implant with the metaphysis, especially at the tibial level (Fig. 2.12).

Debate continues regarding the use of cemented or uncemented stems. Cemented stems are indicated for patients with poor diaphyseal bone and a large canal diameter or for patients whose canal geometry does not allow a reliable press-fit for uncemented stems and those with sclerotic or damaged metaphyseal bone (which results in inadequate fixation, requiring an extension of cementing into the diaphyseal canal). Cemented stem fixation allows the use of shorter stems, provides immediate fixation, and allows

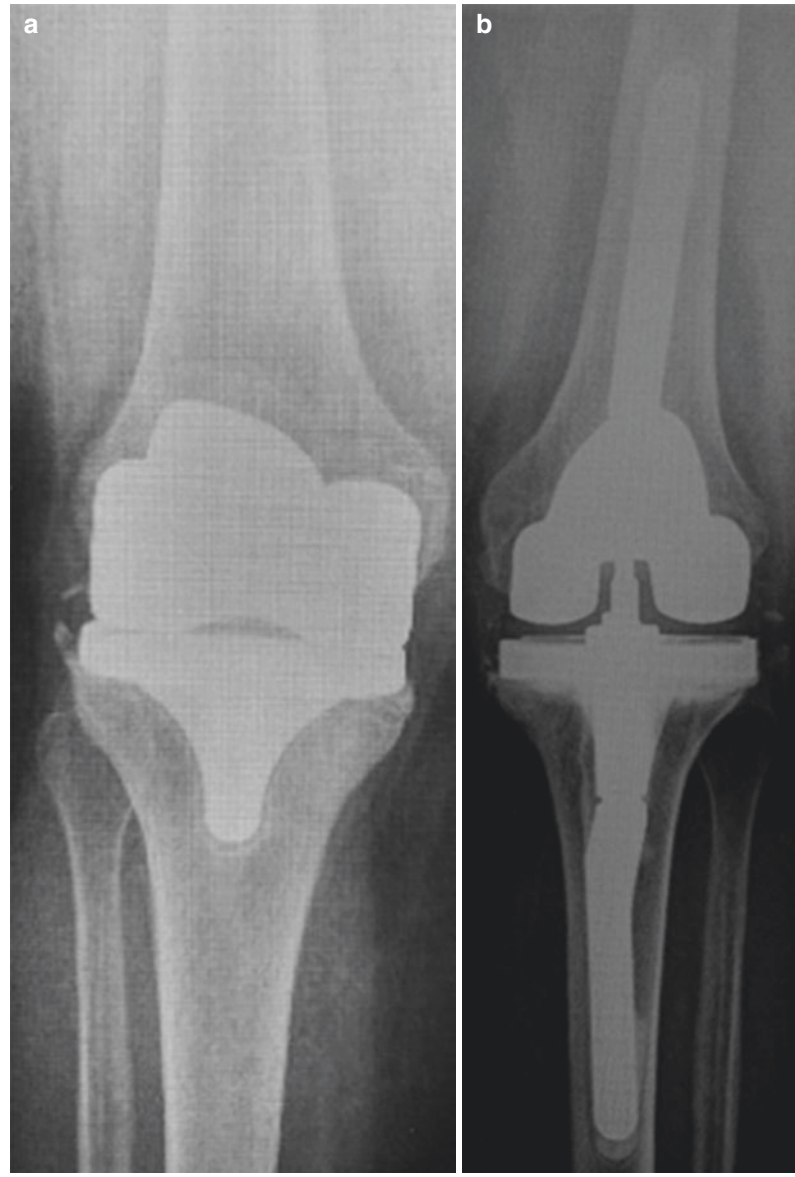

Fig. 2.12 (**a**) Aseptic failed TKA. (**b**) An offset tibial intramedullary stem to allow better alignment of the implant with the tibial metaphysis was used

the use of antibiotics. However, cemented stems may also lead to stress shielding in the metaphysis.

Uncemented stems are preferred for patients with good diaphyseal bone and favorable canal geometry allowing a press-fit. Uncemented stems are also preferred for the management of periprosthetic fractures (Fig. 2.13). Uncemented stems appear to have less stress shielding in the metaphysis.

Successful RTKA requires competent and functional ligaments; the absent medial collateral ligament (MCL) or lateral collateral ligament (LCL) must be compensated. Attempts to reconstruct ligaments with grafts or rerouting of tendons have had generally poor results. Therefore, we usually resort to more constrained implants.

A general principle is to use the minimal amount of implant constraint possible without sacrificing stability. This reduces stress transmission

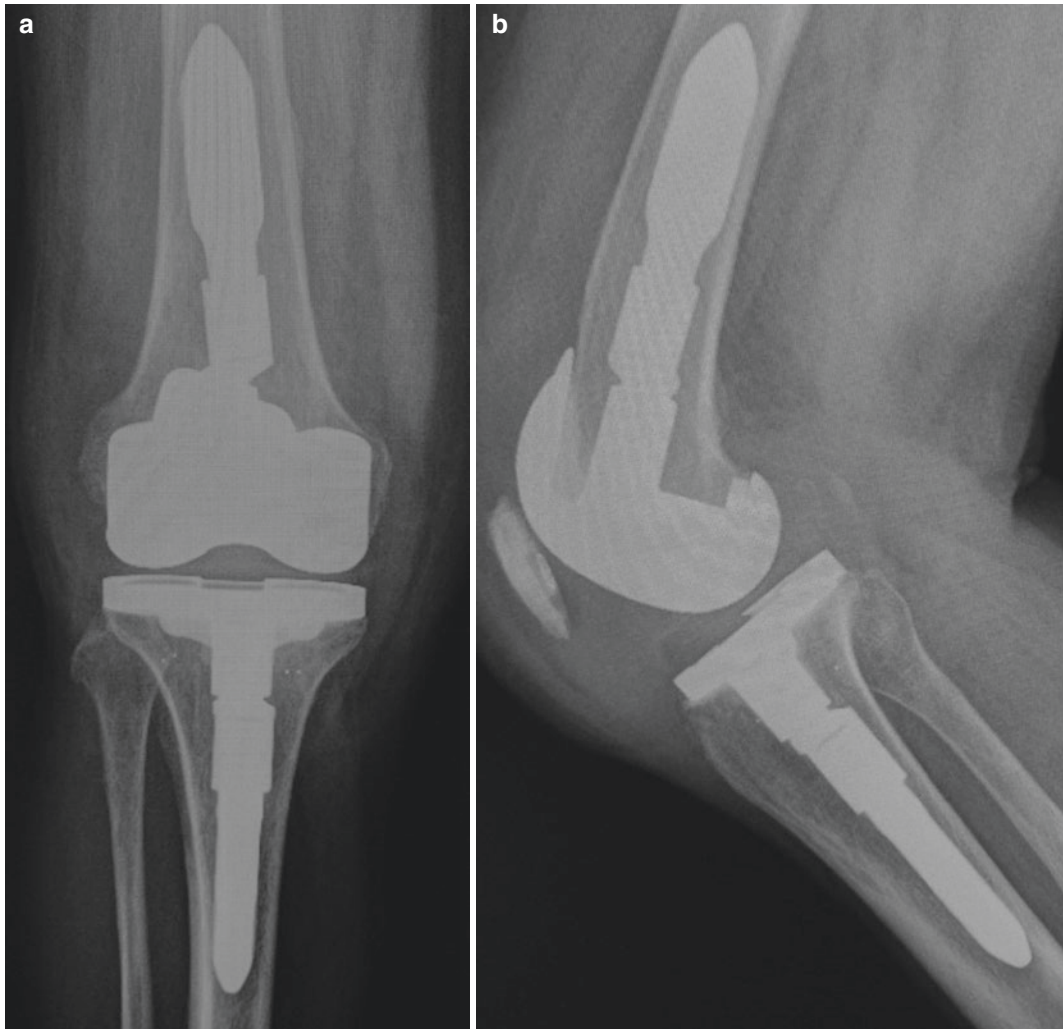

Fig. 2.13 (**a**) Anteroposterior and (**b**) lateral radiographs of uncemented stems in revision TKA (RTKA)

to the cement-bone interface and theoretically will minimize the rate of aseptic loosening.

Use a graduated approach based on the integrity of the collateral ligaments and soft tissue envelope. Posterior stabilization is an option when collateral ligamentous structures are intact. In most revisions, we use posterior-stabilized (PS) TKA because the posterior cruciate ligament is no longer competent. As bone loss and ligamentous support become more compromised, it is also easier to change the PS tibial insert to a constrained design. Constrained condylar knee (CCK) are indicated for patients with insufficiency of the collateral ligaments (unstable for single plane) and moderate bone loss (type II). Rotating-hinge (RH) prostheses are indicated for patients with global instability (absence or disruption of the ligaments and unstable for biplane), severe bone loss (type III), some deficient extensor mechanisms, revision of a previous hinge, comminuted periprosthetic fractures in the elderly, or for complex oncologic reconstruction (Fig. 2.14). The RH platform provides stability, more normal knee kinematics, less wear, and reduced stress transmission to the cement-bone interface. RH are less constrained than typical CCK varus-valgus constrained inserts; they rotate internally or externally allowing motion, while

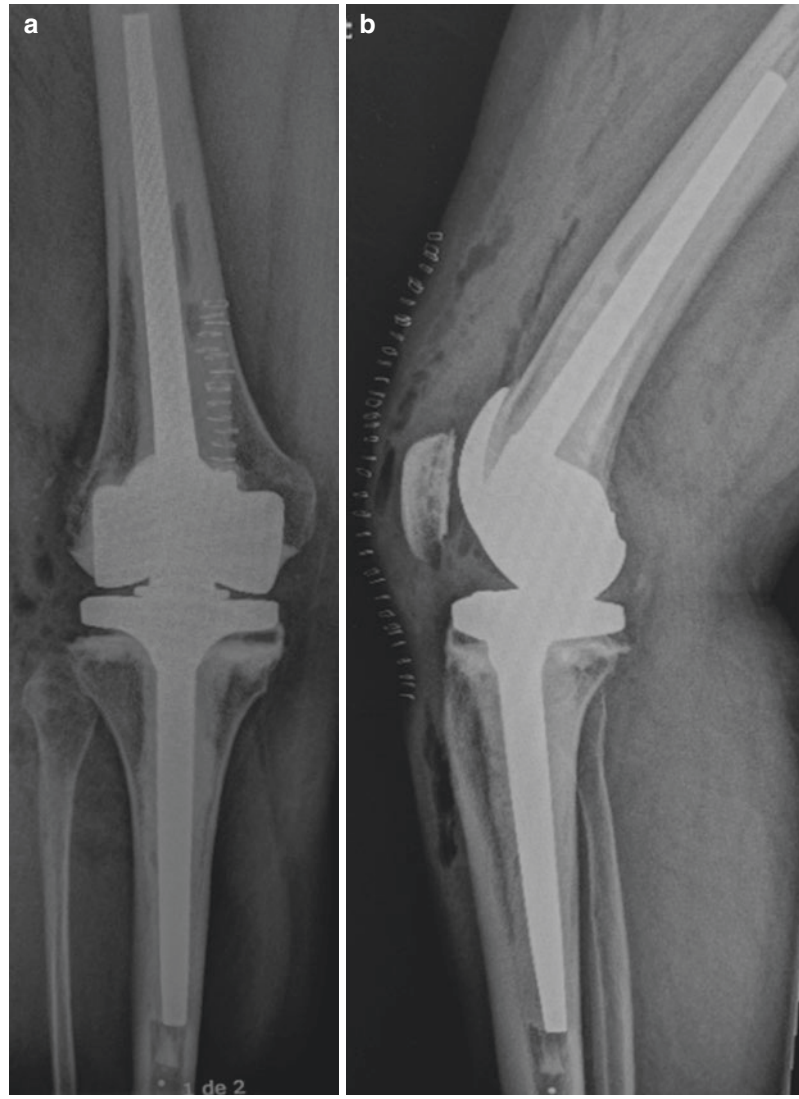

Fig. 2.14 (**a**) Anteroposterior and (**b**) lateral radiographs of revision total knee arthroplasty (RTKA) with a rotating-hinge (RH) design

CCK implants often allow only 2° or 3° of rotation [12–15].

2.4.4 Patella Reconstruction

We measure the bone remnant, and if its thickness is 10–12 mm, it is adequate for implanting a new component cemented in a standard manner. Meticulous removal of fibrous tissue and good cementation technique are important. Patellar component reimplantation can be combined with the grafting of autologous bone from the bony cuts or iliac crest. If the remnant thickness is less than 8–10 mm of cortical bone, complications such component loosening, risk of fracture, or avascular necrosis are possible.

There are several options for the management of severe bone loss (Fig. 2.15):

- No resurfacing and/or patelloplasty (or resection arthroplasty); this implies the simple removal of the patellar implant with or without reshaping of the remnant patellar bone

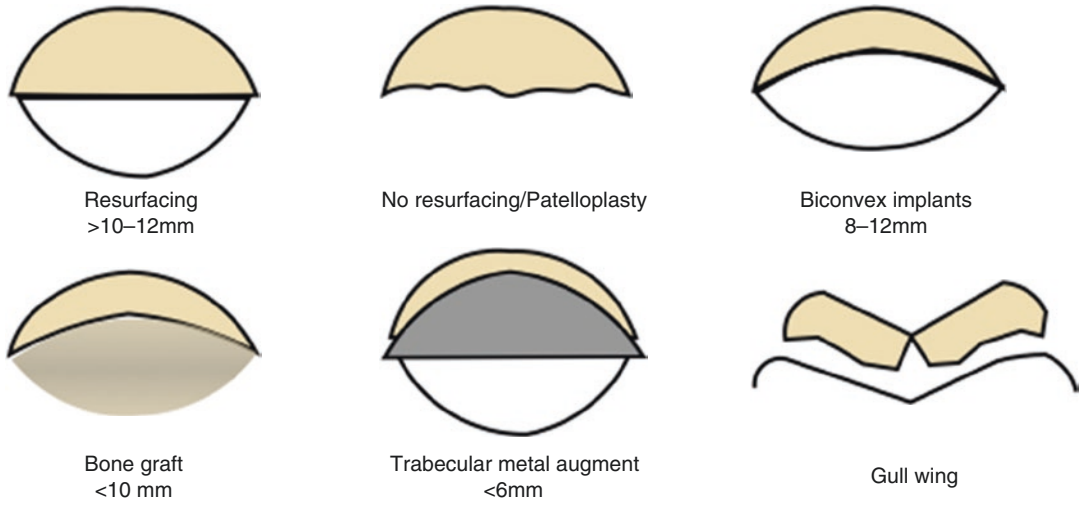

Fig. 2.15 Options for the management of severe patellar bone loss

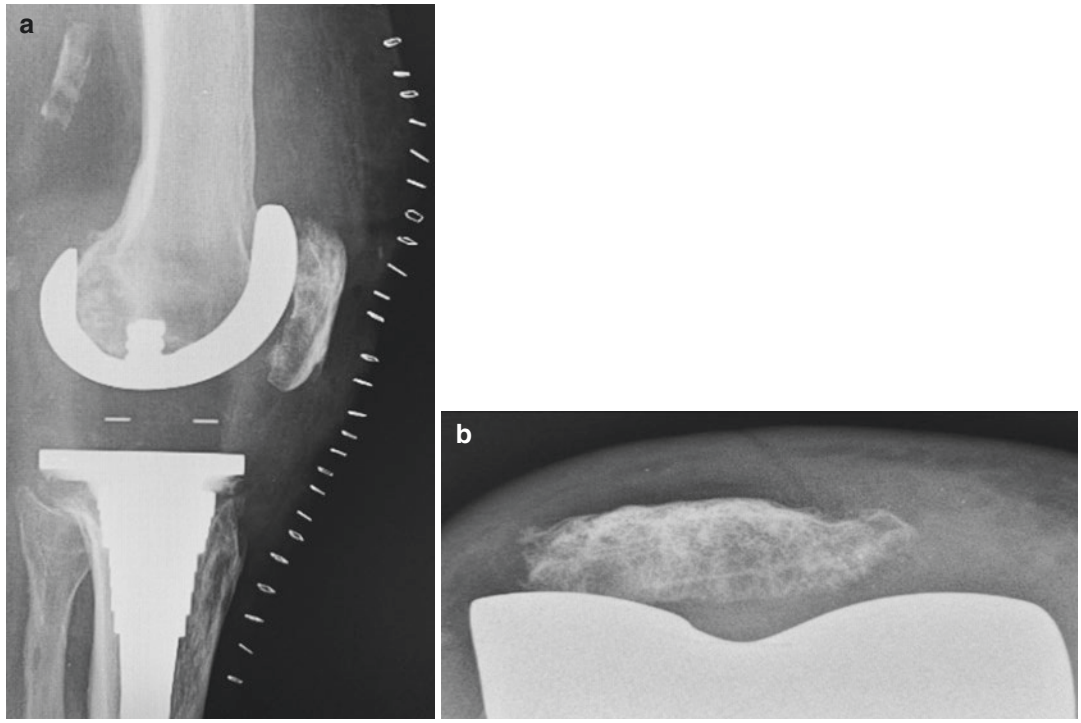

Fig. 2.16 Patelloplasty: (**a**) lateral view; (**b**) skyline view

(Fig. 2.16). Patelloplasty might avoid complications.

- When an intact rim of bone remains but there is too much central cavitary bone, loss biconvex implants can be used.
- Bone grafting reconstruction techniques to restore the bone stock. There are two techniques: structural bone grafting or cancellous bone augmentation. In patients with prior patellectomy, a segment of iliac crest autograft is

harvested and fashioned with shape of the patella [16], or we can use a tissue flap secured to the patellar rim to contain cancellous bone graft inserted into the patellar bone [17]. This technique of patellar bone grafting appears to be an important addition to the armamentarium of surgeons performing RTKA.

- Trabecular metal augments allow filling of the central defect. The surgical technique consists of removing the patellar component and debridement of the fibrous tissue while maintaining the bone ring. Next, we select the appropriate size and fix trabecular metal to the bone with nonabsorbable sutures through peripheral holes and then cement a standard polyethylene into the trabecular metal augment. If 50% or more of the implant is covered by residual bone stock, the result will be good [18].
- Osteotomy, which is a variation of patelloplasty. Vince et al. [19] suggested a gull-wing osteotomy of the patella when further implant revision is not feasible; it is one variation of patelloplasty. The gull-wing osteotomy is a midline sagittal osteotomy made in the articulating surface of the patella, converting a concave thin patellar shell into a V-shaped patella to improve contour and tracking [20].
- Patellectomy, with generally poor clinical results in RTKA with a loss of strength (Fig. 2.17).
- Extensor apparatus allograft. Here, it is important to follow some technical tips: screws are easier than wires to fix the tibial block; recess the bone block to fit into the tibia and self-lock; and suture the graft into the quadriceps in extension; then perform rehabilitation slowly.

None of these techniques has been proven superior to the others [21].

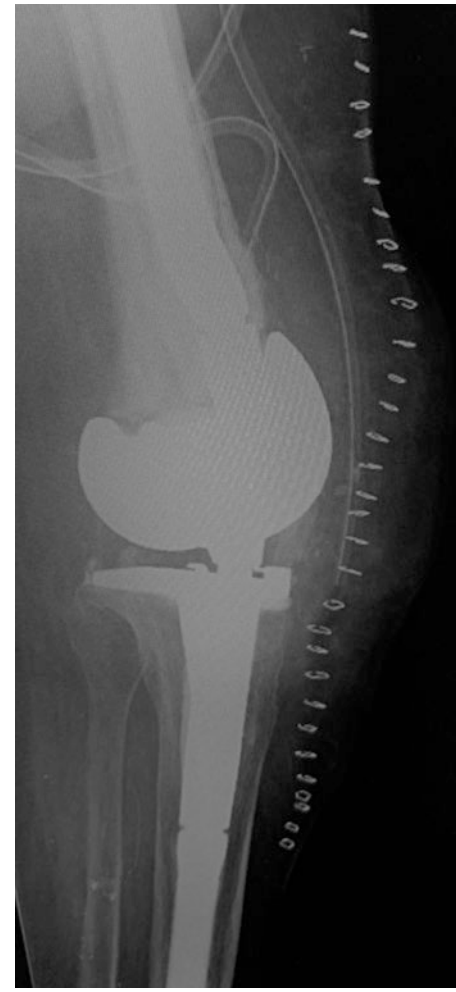

Fig. 2.17 Patellectomy (lateral view)

2.5 Final Preparation

The bone surfaces are cleaned with pulsatile lavage. Then, we use a single-dose local infiltration analgesia (LIA) of 80 cm^3 saline with adrenalin 300 μg, morphine sulfate 10 mg, tobramycin 100 mg, betamethasone sodium phosphate 6 mg, betamethasone acetate 6 mg, and ropivacaine 200 mg diluted with saline to a final volume of 80 cm^3 [22, 23]. We use two batches of cement with antibiotic for each component during the standard RTKA. We place a cement restrictor to prevent leakage of cement into the intramedullary canal. While there are no data comparing the use of a cement restrictor or not, it makes sense that more robust fixation can be achieved with an optimal cement mantle. We apply cement to the surface of the bone and the lower surface of the implant, creating a cement/cement interface. After wound closure in patients without allergies or contraindications to

tranexamic acid (TXA), we use a low-volume formulation of intra-articular tranexamic acid, 25 ml tranexamic acid (2.5 g), plus 20 ml saline to minimize blood loss [24].

2.6 Conclusions

The objective of revision TKA (RTKA) is similar to that of primary TKA: to restore alignment with a stable and securely fixed implant that will allow good functioning and reduce pain. RTKA is not technically easy. It requires special instruments that are not used in primary surgery, and multiple implant options are available. The surgeon needs to be meticulous and patient. Even with experienced and well-prepared surgeons, complications and failures can occur. Using a stepwise approach in RTKA can minimize failures.

References

1. Abdel MP, Della Valle CJ. The surgical approach for revision total knee arthroplasty. Bone Joint J. 2016;98-B(1 Suppl A):113–5.
2. Santore RF, Kaufman D, Robbins AJ, Dabezies EJ Jr. Tissue expansion prior to revision total knee arthroplasty. J Arthroplasty. 1997;12:475–8.
3. Meek RM, Greidanus NV, McGraw RW. The extensile rectus snip exposure in revision of total knee arthroplasty. J Bone Joint Surg. 2003;85:1120–31.
4. Bellemans J. Implant removal in revision total knee arthroplasty. In: Scuderi GR, editor. Techniques in revision hip and knee arthroplasty. Philadelphia, PA: Elsevier; 2015. p. 64–9.
5. Nett MP, Scuderi GR. Revision of aseptic failed total knee arthroplasty. Scott WN(Ed). In: Insall and Scott surgery of the knee. New York, NY: Elsevier; 2018. p. 1897–915.
6. Porteous AJ, Hassaballa MA, Newman JH. Does the joint line matter in revision total knee replacement? J Bone Joint Surg Br. 2008;90:879–84.
7. Lei PF, Hu RY, Hu YH. Bone defects in revision total knee arthroplasty and management. Orthop Surg. 2019;11:15–24.
8. Zanirato A, Formica M, Cavagnaro L, Divano S, Burastero G, Felli L. Metaphyseal cones and sleeves in revision total knee arthroplasty: two sides of the same coin? Complications, clinical and radiological results-a systematic review of the literature. Musculoskelet Surg. 2019; https://doi.org/10.1007/s12306-019-00598-y.
9. Fedorka CJ, Chen AF, Pagnotto MR, Crossett LS, Klatt BA. Revision total knee arthroplasty with porous-coated metaphyseal sleeves provides radiographic ingrowth and stable fixation. Knee Surg Sports Traumatol Arthrosc. 2018;26:1500–5.
10. Divano S, Cavagnaro L, Zanirato A, Basso M, Felli L, Formica M. Porous metal cones: gold standard for massive bone loss in complex revision knee arthroplasty? A systematic review of current literature. Arch Orthop Trauma Surg. 2018;138:851–63.
11. Morgan-Jones R, Oussedik SI, Graichen H, Haddad FS. Zonal fixation in revision total knee arthroplasty. Bone Joint J. 2015;97-B:147–9.
12. Rodríguez-Merchán EC, Gómez-Cardero P, Martínez-Lloreda Á. Revision knee arthroplasty with a rotating-hinge design in elderly patients with instability following total knee arthroplasty. J Clin Orthop Trauma. 2015;6:19–23.
13. Kouk S, Rathod PA, Maheshwari AV, Deshmukh AJ. Rotating hinge prosthesis for complex revision total knee arthroplasty: a review of the literature. J Clin Orthop Trauma. 2018;9:29–33.
14. Bingham JS, Bukowski BR, Wyles CC, Pareek A, Berry DJ, Abdel MP. Rotating-hinge revision total knee arthroplasty for treatment of severe arthrofibrosis. J Arthroplasty. 2019;34:S271–6. pii: S0883-5403(19)30117-2.
15. Rodriguez-Merchan EC. Total knee arthroplasty using hinge joints: indications and results. EFORT Open Rev. 2019;4:121–32.
16. Buechel FF. Patellar tendon bone grafting for patellectomized patients having total knee arthroplasty. Clin Orthop Relat Res. 1991;271:72–8.
17. Hanssen AD. Bone-grafting for severe patellar bone loss during revision knee arthroplasty. J Bone Joint Surg Am. 2001;83:171–6.
18. Ries MD, Cabalo A, Bozic KJ, Anderson M. Porous tantalum patellar augmentation: the importance of residual bone stock. Clin Orthop Relat Res. 2006;452:166–70.
19. Vince K, Roidis N, Blackburn D. Gull-wing sagittal patellarosteotomy in total knee arthroplasty. Tech Knee Surg. 2002;1:106–12.
20. Gililland JM, Swann P, Pelt CE, Erickson J, Hamad N, Peters CL. What is the role for patelloplasty with gullwing osteotomy in tevision TKA? Clin Orthop Relat Res. 2016;474:101–6.
21. Putman S, Boureau F, Girard J, Migaud H, Pasquier G. Patellar complications after total knee arthroplasty. Orthop Traumatol Surg Res. 2019;105:S43–51.

22. Rodriguez-Merchan EC. Single local infiltration analgesia (LIA) aids early pain management after total knee replacement (TKR): an evidence-based review and commentary. HSS J. 2018;14:47–9.
23. Rodriguez-Merchan EC, Vaquero-Picado A, Ruiz-Perez JS. Opioid-free total knee arthroplasty? Local infiltration analgesia plus multimodal blood-loss prevention make it possible. HSS J. 2019;15:17–9.
24. Ortega-Andreu M, Talavera G, Padilla-Eguiluz NG, Perez-Chrzanowska H, Figueredo-Galve R, Rodiiguez-Merchan EC, et al. Tranexamic acid in a multimodal blood loss prevention protocol to decrease blood loss in revision total knee arthroplasty: a cohort study. Open Orthop J. 2016;10:439–47.

3 Revision Total Knee Arthroplasty: Complications and Results

Juan S. Ruiz-Pérez, Primitivo Gómez-Cardero, and E. Carlos Rodríguez-Merchán

3.1 Introduction

Primary total knee arthroplasty (TKA) has proven to be an effective alternative for the treatment of severe osteoarthritis with survival rates at 10–15 years above 90% [1]. Changes in population habits and a longer life expectancy have led to an exponential growth in the number of procedures performed, with an estimated increase of 673% from 2005 to 2030 and 600% (to >250,000 operations) for revision arthroplasty with the consequent secondary economic impact on national health systems [2]. Although the overall annual rate of failure after primary TKA is low, the rate of revision total knee arthroplasty (RTKA) worldwide is increasing. Infection, mechanical loosening, instability, stiffness, and postoperative pain are the most common causes of RTKA, and all-component revision is the most common revision type performed. Typically, although not exclusively, RTKA carried out within 2–5 years after surgery usually corresponds with cases of infection or instability, whereas long-term failures correlate more with aseptic loosening [3].

Reconstruction surgery in cases of revision is technically more complex, and it is essential to identify the cause of the primary failure. Obviously, prosthetic infection entails more difficulties and implies a greater health burden [4]. Preoperative studies should include, in addition to the clinical history seeking signs and symptoms to help identify the cause of the failure, radiological examinations [conventional standing anteroposterior and lateral radiographs, computed tomography (CT) scans] to assess bone defects, serological tests blood tests with acute phase reactants [C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR)], and previous aspiration of synovial fluid (culture) in cases of possible prosthetic infection. Once the etiology of the failure is identified, planning the surgical technique is vital. Consideration should be given to aspects such as skin coverage, soft tissue status, bone stock, and integrity of both the ligament and the extensor mechanism. The use of cemented or cementless stems, cones or sleeves, and augments can facilitate the reconstruction of the joint. Implant technology has been developed to address some of these problems, and the systems now available allow the use of various degrees of constriction and sizes.

Due to the complexity of knee arthroplasty revisions, the high percentage of complications and poorer results is not negligible compared to primary prostheses [5].

J. S. Ruiz-Pérez · P. Gómez-Cardero
E. C. Rodríguez-Merchán (✉)
Department of Orthopedic Surgery,
"La Paz" University Hospital, Madrid, Spain

E. C. Rodríguez-Merchán (ed.), *Revision Total Joint Arthroplasty*,
https://doi.org/10.1007/978-3-030-24773-7_3

3.2 Complications

Given the surgical technique of RTKA is longer and more complex than primary TKA, it has a greater risk of complications. Table 3.1 shows various studies with complication rates around 12–63% [6–10]. In all of them, the implant used was a rotating-hinge prosthesis. From the surgical point of view, given the problem of soft tissue management and bone stock, we should use implants with constricted designs such as constrained condylar knee (CCK) prostheses or rotating hinges [11, 12].

In addition to surgical complications, we must also focus on medical complications. Comorbidities such as obesity and diabetes have been identified as independent risk factors for the appearance of possible postoperative complications.

The possibility that patients with class III obesity [body mass index (BMI) > 40 kg/m^2] have to be operated on TKA is 32 times higher than in normal weight individuals, so is the possibility of suffering postoperative complications in the context of a revision surgery. Carter et al. found a 2.6× increased rate of early complications compared to patients with a normal weight and a higher rate of wound complications (prolonged drainage) in the morbidly obese such as infection or cellulitis [13]. Roth et al. revealed a stronger association between BMI and perioperative complications in RTKA as opposed to revision total hip arthroplasty (RTHA), showing that complication rates after revision total joint arthroplasty increased with BMI but only after a certain threshold [14]. Watts, in his study on aseptic revisions, found that morbid obesity was clearly associated with reoperation, periprosthetic joint infection, and re-revisions compared with the control group [15].

Table 3.1 Complication rates for rotating-hinge designs in revision total knee arthroplasty (RTKA)

Authors	Complications	Complication rate
Smith et al. [6]	Infection (24%), aseptic loosening (7%), periprosthetic fracture (5%)	63%
Baier et al. [7]	Infection (4%), aseptic loosening (6%), arthrofibrosis (7%), patellar complication (3%)	28%
Shen et al. [8]	Infection (12%), aseptic loosening (11%), patellar complication (2%)	22%
Farid et al. [9]	Infection (15%), aseptic loosening (16%), periprosthetic fracture (7%), quad/patellar tendon rupture (4%)	27–56%
Cottino et al. [10]	Infection (11%), aseptic loosening (2.5%), stiffness (2.5%)	12%

The impact of diabetes is well-known and has been linked to an increased risk of mortality, surgical wound infection, and periprosthetic joint infection. It is even considered an independent risk factor for revision due to both septic and aseptic failures [16]. Regarding the type of diabetes, Gu et al. found a complication rate of 31% in patients with insulin dependence, compared with 21.7% for patients not dependent on insulin and 19.7% in patients without diabetes. Insulin-dependent diabetes mellitus was associated with an increased number of serious complications following RTKA, such as septic shock and postoperative blood transfusions [17]. This association necessarily implies the need for strict control of perioperative glycemia, recommending a glycosylated hemoglobin (HbA1c) at levels lower than 8.5 g/dL to prevent potential postsurgical complications [18]. In another study by Gu et al., they found that the male sex was shown to be an independent risk factor for an extended length of stay, infection, failure to wean from drugs postoperatively, and sepsis. The female sex was a risk factor for urinary tract infections. The complication rate was reported to be 13.5% for men and 10.3% for women [19].

Prevention of these complications might be fundamental to the success of the postoperative development after revision surgery.

The main surgical complications include deep or superficial infection, aseptic loosening, disruption of the extensor mechanism and patellar complications, stiffness or arthrofibrosis, and periprosthetic joint fractures.

Regarding the resolution of this type of complication in cases of primary infection, two-stage replacement continues to be the "gold standard."

Periprosthetic joint infection occurs in 8–10% of revisions. Vadiee et al. showed a general failure rate of 26% after a second two-stage arthroplasty and suggested that selected patients with acceptable general health and a culture-sensitive microorganism typically result in a satisfactory outcome [20]. On the other hand, patients with *S. aureus* methicillin-resistant (SAMR) or polymicrobial infections should be evaluated considering options such as amputation or fusion (Fig. 3.1).

However, in recent years, multiple studies have advocated the strategy of one-stage revision with the following contraindications: significant soft tissue compromise, significant bone loss, or generalized sepsis [21]. In the case of acute infections of primary arthroplasties, various success rates have been reported with debridement, antibiotics, and implant retention (DAIR). Ottesen et al. noted in a recent study an overall success rate of 84% with a minimum follow-up of 2 years [22].

Aseptic loosening or instability may be resolved using implants with a higher degree of constriction with the help of augments, cone, or sleeves (Fig. 3.2).

Stiffness and arthrofibrosis are usually treated with rehabilitation programs, manipulation under anesthesia, open or arthroscopic debridement [23], and finally revision arthroplasty.

Extensor mechanism disruption is a devastating complication. In a recent review [24], reconstruction of patellar tendon rupture has a much lower complication rate than repair. However, these techniques can lead to up to a 25% reinfection rate, rupture, and 44% extension lag. Newer techniques such a synthetic mesh augmentation (Fig. 3.3) and gastrocnemius rotational flap should be considered [25].

Periprosthetic fractures associated with knee arthroplasty can be managed conservatively or operatively with osteosynthesis (locking plates or intramedullary nail) or a knee revision system if the fracture compromises the stability of the implant. In the current literature, locking plates (Fig. 3.4) have shown better results than more traditional plates, even though in a recent meta-analysis, no differences were found in terms of delayed union, operating times, and rates of complications between clinical results of locking plates and retrograde intramedullary nails [26].

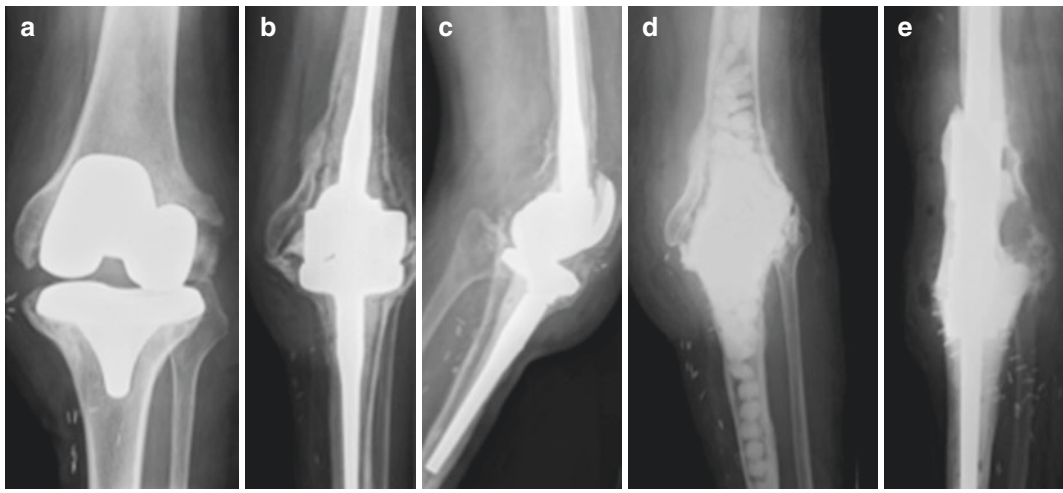

Fig. 3.1 Patient with recalcitrant total knee arthroplasty (TKA) infection not cured after a two-stage revision total knee arthroplasty (RTKA) and requiring a knee arthrodesis. Phases from the failure of the primary prosthesis to the final fusion: (**a**) anteroposterior (AP) view of the infected primary TKA; (**b**) AP radiograph of the rotating hinge implanted (two-stage revision arthroplasty); (**c**) lateral view of the rotating hinge; (**d**) the rotating hinge was removed because of the persistence of infection, and antibiotic-loaded cement and spacer were implanted; (**e**) definitive fusion with an intramedullary device

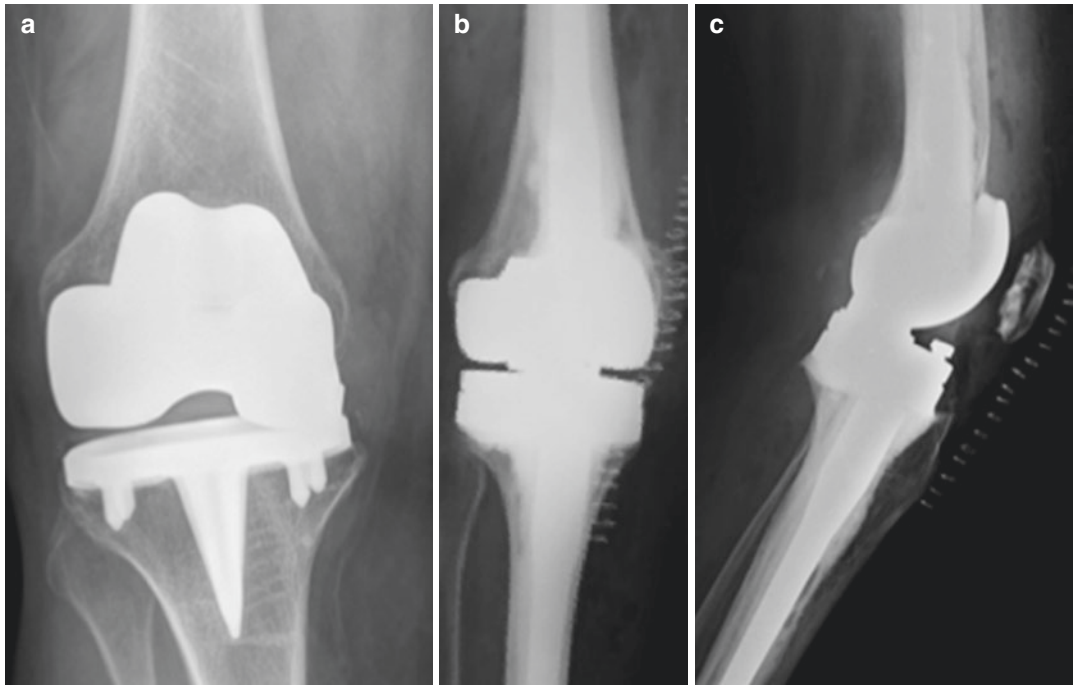

Fig. 3.2 Polyethylene wear and instability resolved with a rotating-hinge prosthesis: (**a**) preoperative AP view; (**b**) postoperative AP view of the rotating hinge implanted; (**c**) postoperative lateral radiograph of the rotating hinge

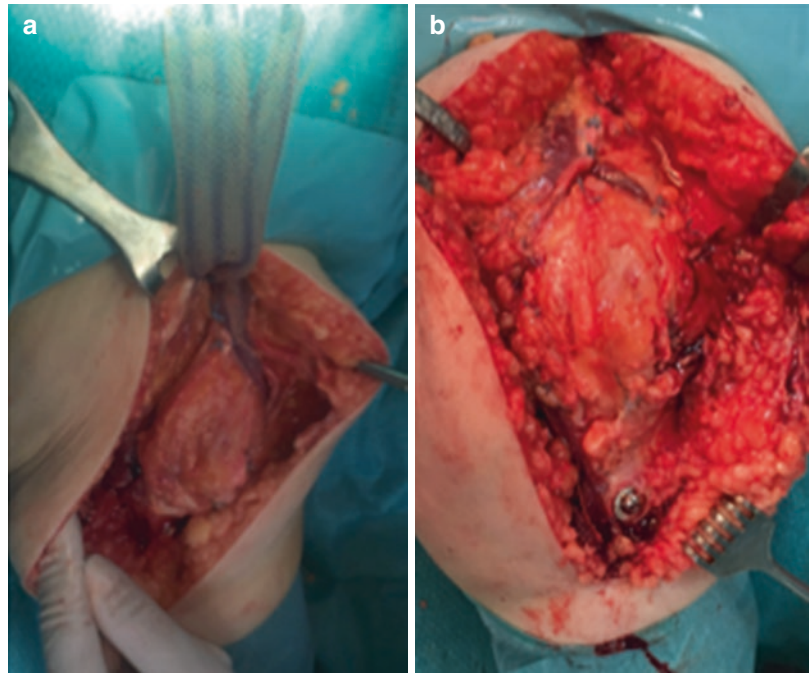

Fig. 3.3 Mesh augmentation of disruption of patellar tendon: (**a**) polypropylene mesh size; (**b**) definitive reconstruction

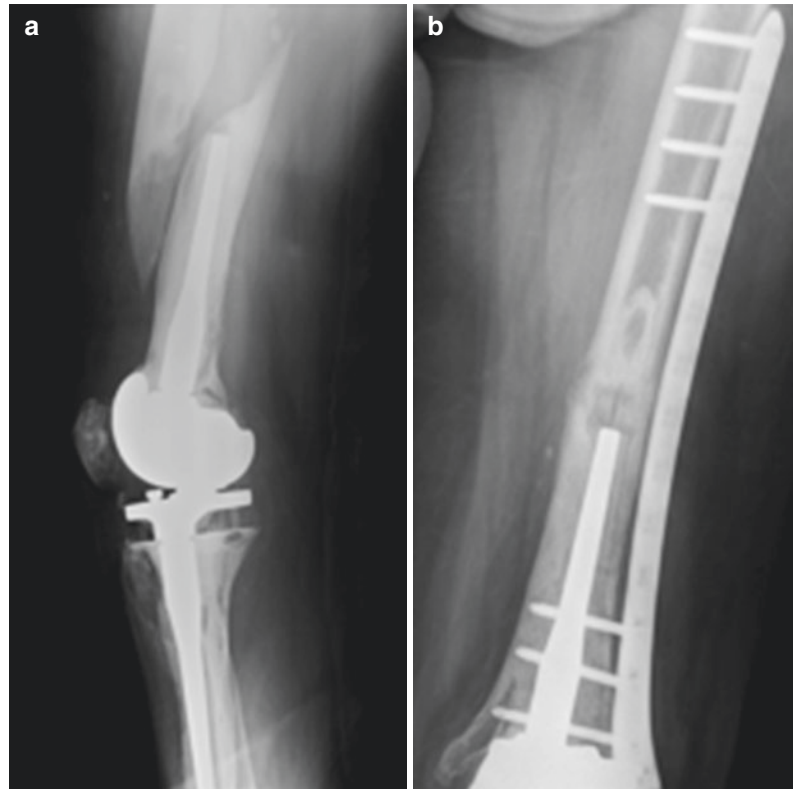

Fig. 3.4 Periprosthetic fracture in rotating-hinge prosthesis managed with a locking plate: (**a**) lateral view of the fracture, (**b**) AP view after fixing the fracture

3.3 Results

Despite the development of new implants, better strategies for the management of antibiotics, and perioperative optimization of patients, the results of RTKA are slightly poorer compared to primary cases. Survival rates of revision surgery are reported to be approximately 80% at 10 years. Among them, survival of late revision arthroplasties is significantly better than early revision (within 2 years), with revision failure rates of 17% and 2%, respectively, according to Hardeman et al. [27].

Similarly, revisions carried out in the context of a septic case usually report poorer results. It is difficult to determine the success of this procedure given the heterogeneity of the studies in terms of the causes of primary failure (partial or full components revision) and the implants used (posterior stabilized, hinged or inked implants, cemented or cementless). Rajgopal et al. [28] suggest that revision knee arthroplasty for flexion instability secondary to an undersized femoral component or over-resection of bone from the posterior femoral condyles has poorer outcomes compared with those undergoing revision surgery for infection or aseptic loosening.

Implant failure and the subsequent need for revision continue to place a major economic burden on healthcare [29]. In Table 3.2 we summarize the results of recent and classic studies available in the literature [3, 6, 7, 9, 10, 30, 31].

Lee et al. [31] asserts that there has been a change in the trend of causes of knee revision. This trend is corroborated by current epidemiological studies carried out in the United States. Six percent of TKA patients will need a revision within 5 years. Mechanical complications such as aseptic loosening and instability leading to revision have decreased, while septic failures seem to be increasing. In the study of Lee et al., clinical outcome scores such as the Knee Society score (KSS) were more satisfying in the aseptic complication group at statistically significant levels.

Lee et al. concluded that we should be watchful for infection after TKA and not ignore risk factors such as diabetes mellitus, smoking, malnutrition, and older age.

From a surgical point of view, restoring the joint line is considered fundamental to achieving a good clinical outcome. Correction of alignment, balance of the flexion—extension gap—and assurance of the correct patellar height should be kept in mind. Bone stock loss is a challenge for this reason. It is estimated that the joint line remains elevated by more than 5 mm in 36–79% of RTKAs. Han et al. [32] found that restoration of the distal femoral joint line was the only significant factor that increased postoperative range of movement (ROM) of the knee after RTKA, while tibial joint line elevation or patellar height change showed no significant effect on ROM after surgery.

Table 3.2 Results and survival rates in revision total knee arthroplasty (RTKA)

Authors	Results	Survival rate
Smith et al. [6]	–	52% at 5 years
Baier et al. [7]	KSS 57 → 71	–
Farid et al. [9]	KSS 36 → 77	73% at 5 years, 51% at 10 years
Cottino et al. [10]	KSS 51 → 81	84.5% at 5 years, 71.3% at 10 years
Hossain et al. [3]	KSS 31 → 84	92.5% at 5 years
Deehan et al. [30]	KSS 28 → 74	90% at 5 years
Lee et al. [31]	KSS 44 → 82	–

KSS = Knee Society score

For severe bone stock loss management (Anderson Orthopedic Research Institute classification type 2 and 3), cement, long stem, metal augments, allograft, titanium sleeve, and trabecular metal cones can be alternatives to rotating hinged designs (Fig. 3.5). A systematic review [33] showed that porous metal cones and titanium sleeves were effective for bone defect management during RTKA.

In terms of correction of alignment and diaphyseal fixation, there is still debate and comparison between cemented and cementless stems. Based on the available literature, no superiority of any type of stem fixation has been found. In terms of the rate of specific complications of aseptic loosening or infection, no differences have been observed. Both cemented and cementless intramedullary stems fixations appear to have comparable stability and durability [34]. In a recent review, the data support their equivalence. It is

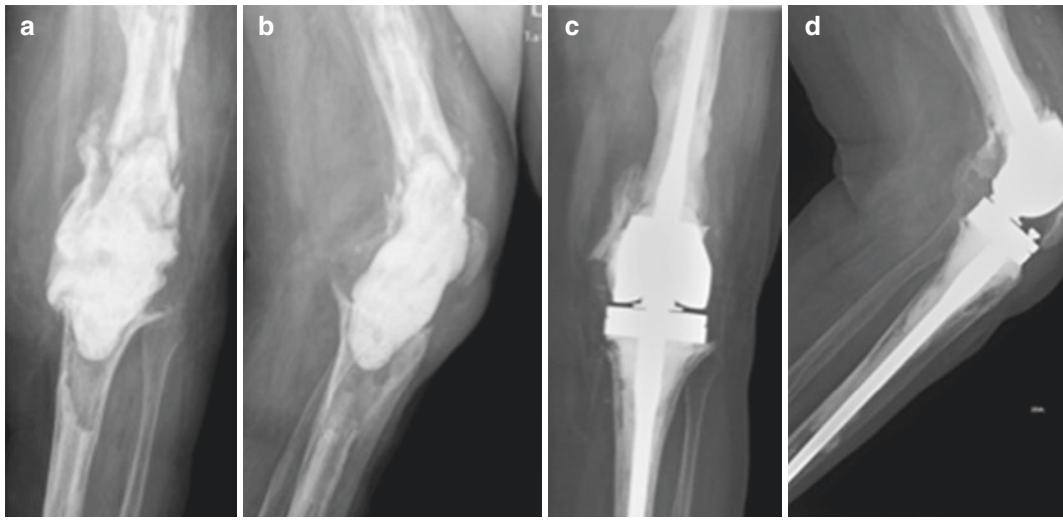

Fig. 3.5 Severe bone stock loss solved with a rotating-hinge prosthesis: (**a**) AP view of the implanted handmade cement spacer; (**b**) lateral view of the spacer; (**c**) AP view of the rotating-hinge prothesis; (**d**) lateral view of the rotating hinge

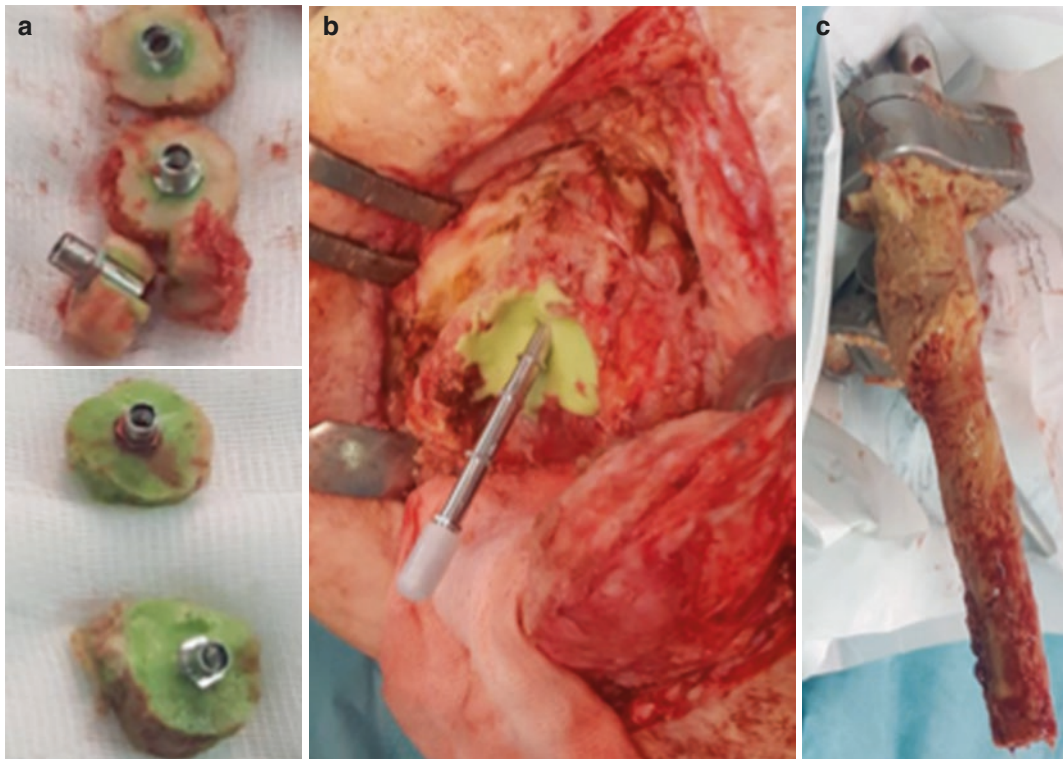

Fig. 3.6 CEMOVER (A2C) system used to remove cemented stems in RTKA: (**a**) fragments of diaphyseal cement; (**b**) intramedullary stainless steel cylinders; (**c**) tibial component removed

clear that no consensus can be achieved on these techniques [35]. Advantages and disadvantages of both types of fixation have been summarized by Kang et al. [36], and they noted that stem length and diameter should be individualized according to the patients' anatomical characteristics. Most surgeons use a hybrid fixation, although in our institution, we prefer cemented stems given we are faced with cases with large bone defects, poor quality due to the age of our patients, the possibility of adding local antibiotic therapy to cement, and our consideration that the technique is more reproducible. Cement can be difficult to remove, especially in the context of infection. Currently there are novel systems available that allow their extraction more easily (Fig. 3.6).

Finally, one of the most important issues is the need to centralize the most complex cases in centers with the highest volume of revision to achieve better results with fewer complications and lower mortality. The Scottish Arthroplasty Project records that 30% of surgeons currently carrying out RTKA perform fewer than five a year. The cutoff point in terms of the number of annual surgeries to consider an orthopedic surgeon an expert in prosthetic revisions is controversial, although logically it requires a broad knowledge of anatomical references, implant design, and reconstruction options. On many occasions, a multidisciplinary team is needed with the collaboration of vascular and plastic surgeons, microbiologists, and infectious diseases specialists [5, 36].

3.4 Conclusions

Revision total knee arthroplasty (RTKA) is a challenge from the surgical point of view. The exponential increase in the demand for this type of procedure means orthopedic surgeons must understand the most frequent causes of primary

failure as well as the design of new implants and alternatives for the reconstruction of large bone defects. The ultimate objective is to achieve a functional joint, pain relief, and an acceptable prosthetic survival rate, taking into account the complexity of each case. Given the possible complications and the desire to achieve the best results, it is best for this type of surgery to be carried out in large institutions with a high annual volume of cases and with the collaboration of a multidisciplinary team.

References

1. Mistry JB, Elmallah RK, Chughtai M, Oktem M, Harwin SF, Mont MA. Long-term survivorship and clinical outcomes of a single radius total knee arthroplasty. Surg Technol Int. 2016;28:247–51.
2. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am. 2007;89:780–5.
3. Hossain F, Patel S, Haddad FS. Midterm assessment of causes and results of revision total knee arthroplasty. Clin Orthop Relat Res. 2010;468:1221–8.
4. Kerkhoffs GM, Servien E, Dunn W, et al. The influence of obesity on the compli cation rate and outcome of total knee arthroplasty: a meta-analysis and systematic literature review. J Bone Joint Surg Am. 2012;94-A:1839–44.
5. Hamilton DF, Howie CR, Burnett R, Simpson AH, Patton JT. Dealing with the predicted increase in demand for revision total knee arthroplasty: challenges, risks and opportunities. Bone Joint J. 2015;97-B:723–8.
6. Smith TH, Gad BV, Klika AK, Styron JF, Joyce TA, Barsoum WK. Comparison of mechanical and nonmechanical failure rates associated with rotating hinged total knee arthroplasty in nontumor patients. J Arthroplasty. 2013;28:1)10.1016.
7. Baier C, Lüring C, Schaumburger J, et al. Assessing patient-oriented results after revision total knee arthroplasty. J Orthop Sci. 2013;18(6):955–61. https://doi.org/10.1007/s00776-013-0467-1.
8. Shen C, Lichstein PM, Austin MS, Sharkey PF, Parvizi J. Revision knee arthroplasty for bone loss: choosing the right degree of constraint. J Arthroplasty. 2014;29:127–13110.1016.
9. Farid YR, Thakral R, Finn HA. Intermediate-term results of 142 single-design, rotating-hinge implants: frequent complications may not preclude salvage of severely affected knees. J Arthroplasty. 2015;30:2173–80. https://doi.org/10.1016/j.arth.2015.06.033.
10. Cottino U, Abdel MP, Perry KI, Mara KC, Lewallen DG, Hanssen AD. Long-term results after total knee arthroplasty with contemporary rotating-hinge prostheses. J Bone Joint Surg Am. 2017;99:324–30.
11. Rodríguez-Merchán EC, Gómez-Cardero P, Martínez-Lloreda A. Revision knee arthroplasty with a rotating-hinge design in elderly patients with instability following total knee arthroplasty. J Clin Orthop Trauma. 2015;6:19–23.
12. Rodríguez-Merchán EC. Total knee arthroplasty using hinge joints: indications and results. EFORT Open Rev. 2019;4:121–32.
13. Carter J, Springer B, Curtin BM. Early complications of revision total knee arthroplasty in morbidly obese patients. Eur J Orthop Surg Traumatol. 2019;29:1101. https://doi.org/10.1007/s00590-019-02403-9.
14. Roth A, Khlopas A, George J, Churchill JL, Molloy R, Mont MA, Piuzzi NS, Higuera CA. The effect of body mass index on 30-day complications after revision total hip and knee arthroplasty. J Arthroplasty. 2019;37:S242. https://doi.org/10.1016/j.arth.2019.02.005. pii: S0883-5403(19)30140-8.
15. Watts CD, Wagner ER, Houdek MT, Lewallen DG, Mabry TM. Morbid obesity: increased risk of failure after aseptic revision TKA. Clin Orthop Relat Res. 2015;473:2621e7.
16. Namba RS, Cafri G, Khatod M, Inacio MC, Brox TW, Paxton EW. Risk factors for total knee arthroplasty aseptic revision. J Arthroplasty. 2013;28(8 Suppl):122–7.
17. Gu A, Wei C, Robinson HN, Sobrio SA, Liu J, Sculco TP, Sculco PK. Postoperative complications and impact of diabetes mellitus severity on revision total knee arthroplasty. J Knee Surg. 2019; https://doi.org/10.1055/s-0038-1677542.
18. Underwood P, Askari R, Hurwitz S, Chamarthi B, Garg R. Preoperative A1C and clinical outcomes in patients with diabetes undergoing major noncardiac surgical procedures. Diabetes Care. 2014;37(3):611–6.
19. Gu A, Wei C, Bernstein SA, Nguyen NTT, Sobrio SA, Liu J, Sculco PK. The impact of gender on postoperative complications after revision total knee arthroplasty. J Knee Surg. 2019; https://doi.org/10.1055/s-0039-1677820.
20. Vadiee I, Backstein DJ. The effectiveness of repeat two-stage revision for the treatment of recalcitrant total knee arthroplasty infection. J Arthroplasty. 2019;34:369–74.
21. Rowan FE, Donaldson MJ, Pietrzak JR, Haddad FS. The role of one stage exchange for prosthetic joint infection. Curr Rev Musculoskelet Med. 2018;11:370–9.
22. Ottesen CS, Troelsen A, Sandholdt H, Jacobsen S, Husted H, Gromov K. Acceptable success rate in patients with periprosthetic knee joint infection treated with debridement, antibiotics, and implant retention. J Arthroplasty. 2019;34:e365–8.
23. Encinas-Ullán CA, Rodríguez-Merchán EC. Arthroscopic treatment of total knee arthroplasty complications. EFORT Open Rev. 2019;4:33–43.
24. Vajapey SP, Blackwell RE, Maki AJ, Millet TL. Treatment of extensor tendon disruption after total

knee arthroplasty: a systematic review. J Arthroplasty. 2019. pii: S0883-5403(19)30202-5.
25. Morrey MC, Barlow JD, Abdel MP, Hanssen AD. Synthetic mesh augmentation of acute and subacute quadriceps tendon repair. Orthopedics. 2016;39(1):e913.
26. Li B, Gao P, Qiu G, Li T. Locked plate versus retrograde intramedullary nail for periprosthetic femur fractures above total knee arthroplasty: a meta-analysis. Int Orthop. 2016;40:1689–95.
27. Hardeman F, Londers J, Favril A, et al. Predisposing factors which are relevant for the clinical outcome after revision total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc. 2012;20:1049–56.
28. Rajgopal A, Panjwani TR, Rao A, Dahiya V. Are the outcomes of revision knee arthroplasty for flexion instability the same as for other major failure mechanisms? J Arthroplasty. 2017;32:3093–7.
29. Delanois RE, Mistry JB, Gwam CU, Mohamed NS, Choksi US, Mont MA. Current epidemiology of revision total knee arthroplasty in the United States. J Arthroplasty. 2017;32:2663–8.
30. Deehan DJ, Murray J, Birdsall PD, Holland JP, Pinder IM. The role of the rotating hinge prosthesis in the salvage arthroplasty setting. J Arthroplasty. 2008;23:683–8. https://doi.org/10.1016/j.arth.2007.05.055.
31. Lee DH, Lee SH, Song EK, Seon JK, Lim HA, Yang HY. Causes and clinical outcomes of revision total knee arthroplasty. Knee Surg Relat Res. 2017;29:104–9.
32. Han HS, Yu CH, Shin N, Won S, Lee MC. Femoral joint line restoration is a major determinant of postoperative range of motion in revision total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc. 2019;27:2090. https://doi.org/10.1007/s00167-019-05361-1.
33. Kim HJ, Lee OS, Lee SH, Lee YS. Comparative analysis between cone and sleeve in managing severe bone defect during revision total knee arthroplasty: a systematic review and meta-analysis. J Knee Surg. 2018;31:677–85.
34. Wang C, Pfitzner T, von Roth P, Mayr HO, Sostheim M, Hube R. Fixation of stem in revision of total knee arthroplasty: cemented versus cementless-a meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2016;24:3200–11.
35. Driesman AS, Macaulay W, Schwarzkopf R. Cemented versus cementless stems in revision total knee arthroplasty. J Knee Surg. 2019; https://doi.org/10.1055/s-0039-1678686.
36. Kang SG, Park CH, Song SJ. Stem fixation in revision total knee arthroplasty: indications, stem dimensions, and fixation methods. Knee Surg Relat Res. 2018;30:187–92.

4 Revision Total Hip Arthroplasty: Epidemiology and Causes

Ricardo Fernández-Fernández, Ana Cruz-Pardos, and Eduardo García-Rey

4.1 Introduction

Total hip arthroplasty (THA) provides excellent long-term results. However, no implant will last forever, and with time it will need to be revised. The question of how long does a THA last is a frequently posed question in the medical literature and one that is often voiced by patients scheduled for a hip replacement [1]. The National Institute for Health and Care Excellence (NICE) requires a 95% survivorship at 10 years follow-up for a primary replacement [2].

Revision procedures provide inferior results with lower survivorship than primary arthroplasties and are at a higher risk for failure [3]. Revision patients are often elderly and fragile, with limited bone stock and debilitated soft tissues. The surgeon faces challenging problems such as difficult component removal, previous scar tissue with complicated exposures, femoral deformities, component instability, prior fracture nonunions, and infection [4–7].

The number of hip revisions has been increasing in recent years due to several causes [5]: the growing use of total hip arthroplasties across ever-larger age groups, longer life expectancies, etc. The etiology of hip revision has evolved and differs between the numerous published studies and national registries. This reflects the variability in surgical practice in both primary and revision hip arthroplasty. Classically, aseptic loosening was the primary cause for revision [8]. According to the National Inpatient Sample (NIS) data, the most frequent causes for revision in the USA are instability and implant loosening, accounting for 17.3% and 16.8% of procedures, respectively [9].

Registry data provide extensive information about the different etiologies of hip revision, analyzing patient characteristics (i.e., age, gender, American Society of Anesthesiologists (ASA), body mass index (BMI), activity levels, diagnosis), surgical technique (i.e., approach, type of fixation), and implant type (i.e., stem design, cup design, weight-bearing surface). The single variable that is monitored in every registry is implant survivorship. Registries focus on patients who have undergone a revision, and data relates to different implants, patient characteristics, and surgical techniques employed. Quality data across different registries has been assessed: the capture rate must be over 95% of the procedures and with a low loss to follow-up [10].

The 25-year survivorship of THA for primary osteoarthritis, according to Australian and Finish registries, is 58% (95% CI 57.1–58.7) [1]. Many case series report higher survival rates of around 70% at 25 years, which suggests some possible sources of bias. Case series usually come from

R. Fernández-Fernández (✉) · A. Cruz-Pardos
E. García-Rey
Department of Orthopedic Surgery,
"La Paz" University Hospital, Madrid, Spain
e-mail: ricardo.fernandez@salud.madrid.org

E. C. Rodríguez-Merchán (ed.), *Revision Total Joint Arthroplasty*,
https://doi.org/10.1007/978-3-030-24773-7_4

high-volume centers and high-volume surgeons, which are more prone to publishing favorable results [11]. Innovative surgeons with strong relationships with prosthetic industry manufacturers usually report better results than national registries [12].

Registries are limited by the data provided by too many different specialists. Most of the registries also lack clinical information such as reported pain and function of existing implants. Clinical information should include patient-reported result outcome measures, validated hip clinical scores, hospital, and various implant-related factors [13]. At present, there are registries in North America, Australia, and New Zealand and 24 registries in Europe (15 of these are national). Few registries record implant-related complications or medical complications other than the ones in which revision surgery was required. In recent years, a greater interest in Patient Reported Outcome Measures (PROMs) now means these are being more frequently collected. Table 4.1 summarizes the number of procedures, coverage, and variables recorded in some of the larger registries [2, 13–20].

Primary diagnosis affects the survivorship of THA. Development hip dysplasia, inflammatory degenerative arthritis, osteonecrosis, and femoral

Table 4.1 Overview of the most popular registries with the different outcomes reported in each of them

Registry (year)	Sweden (1979)	Finland (1980)	Norway (1987)	Denmark (1995)	Australia (1999)	NJR (2002)
THA primaries	267,714	206,379	190,298	149,154	437,863	992,090
THA revisions	24,447	40,649	31,515	23,430	66,467	27,605
Coverage	93%	95%	95%	97.5%	98.8%	97%
Outcomes						
Revision	X	X	X	X	X	X
Mortality	X	X	X	X	X	X
Infection	X	X		X		X
Dislocation	X	X				
Periprosthetic fracture	X					
PROMs	X			X		X
Readmission	X	X		X		X
Reoperation	X	X		X		
Costs	X					X
Patients						
Age	X	X	X	X	X	X
Gender	X	X	X	X	X	X
BMI	X	X		X	X	X
Diagnosis	X	X	X	X	X	X
Previous surgery		X				X
ASA	X	X	X	X	X	X
Charnley	X			X		
Surgery						
Type of hospital	X		X	X	X	X
Volume	X		X	X	X	X
Approach	X	X	X	X	X	X
Surg time		X	X		X	X
Antibiotics		X	X	X	X	X
Anticoagulation		x	x	x	X	X
Implant details	X	X	X	X	X	X
Fixation	X	X	X	X	X	X
Bearing surface	X		X	X	X	X

The "X" indicates which registries collected that variable
NRJ National Joint Registry of England, Wales, and Northern Ireland

neck fracture show less favorable results than primary osteoarthritis (OA) [21]. Primary OA constitutes the main diagnosis in over 85% of patients who receive a total hip replacement. In OA, the age at the time of the index procedure is the key factor which predicts the lifetime risk of revision [22].

Implant selection plays a crucial role in joint survivorship. New implants have not always shown better results than existing ones. The Orthopedic Data Evaluation Panel provide records of implant survivorship at different times of follow-up, producing 3-, 5-, 7-, and 10-year revision rates. At present, it only provides revision rates pertaining to the constituent parts of the arthroplasty. The National Joint Registry of England, Wales, and Northern Ireland (NJR) found that 27% of hip implants introduced between 2003 and 2007 showed a higher revision rate than existing prostheses [23]. Registries allow the detection of suboptimal performance of new implants during the first years [19]. This monitoring helps prevent implant-related complications and aids the decision-making process when deciding which implant to use. Tables 4.2 and 4.3 summarize the best-performing cemented and uncemented hip implants.

Table 4.2 Cumulative percent of revision of primary total conventional hip replacement with cemented fixation in the NJR and AOANJRR: Revision risk (%) for implants with at least one registry reporting 10-year data

Stem-cup	Number	Registry	5 years	10 years
MS-30/low-profile Müller	3534	NJR	0.75 (0.4–1.1)	1.72 (1.1–2.6)
	721	AOANJRR	1.4 (0.7–2.7)	2.9 (1.7–4.8)
Exeter V40/contemporary	77,380	NJR	1.29 (1.2–1.3)	2.34 (2.1–2.5)
	5513	AOANJRR	3.6 (3.1–4.2)	6.3 (5.5–7.4)
Charnley/Charnley	4560	NJR	1.74 (1.3–2.1)	3.47 (2.9–4.1)
	591	AOANJRR	2.2 (1.2–3.8)	6.2 (4.4–8.8)
CPT/ZCA	14,872	NJR	2.02 (1.7–2.3)	3.62 (3.1–4.1)
	951	AOANJRR	2.8 (1.9–4.2)	5 (3.5–7.2)
Stanmore/Stanmore-Arcom	5382	NJR	1.54 (1.2–1.9)	2.42 (1.9–3)

Only data of stem-cup combinations that did not mix different manufacturers are displayed. The number of implants and revision risks at 5- and 10-year follow-up are presented

NRJ National Joint Registry of England, Wales, and Northern Ireland, *AOANJRR* Australian Orthopedic Association National Joint Replacement Registry

Table 4.3 Cumulative percent of revision of primary total conventional hip replacement with uncemented fixation in the NJR and AOANJRR: Revision risk (%) for implants with at least one registry reporting 10-year data

Stem-cup	Number	Registry	5 years	10 years
Taperloc/Exceed ABT	22,851	NJR	1.83 (1.6–2)	2.16 (1.9–2.4)
	2270	AOANJRR	2.4 (1.9–3.2)	
Furlong/CSF	17,173	NJR	2.15 (1.9–2.3)	3.6 (3.3–3.9)
Summit/Pinnacle	4688	AOANJRR	2.3 (1.9–2.8)	3.3 (2.7–4.1)
Corail/Pinnacle	137,857	NJR	2.44 (2.3–2.5)	5.96 (5.7–6.2)
	42,405	AOANJRR	3.4 (3.2–3.6)	5.6 (5.1–6.4)
Accolade/Trident	26,073	NJR	2.61 (2.4–2.8)	4.46 (4–4.9)
	9288	AOANJRR	3.8 (3.4–4.2)	5.7 (5.2–6.2)
Synergy/Reflection	7966	AOANJRR	2.7 (2.4–3.1)	4.0 (3.6–4.5)
Alloclassic/Allofit	5791	AOANJRR	3.1 (2.7–3.6)	5.4 (4.8–6.1)
Securfit/Trident	9642	AOANJRR	3.4 (3.1–3.8)	4.6 (4.1–5.1)
SL Plus/Epifit	5402	NJR	3.78 (3.2–4.3)	5.83 (5.1–6.6)
	2300	AOANJRR	3.5 (2.8–4.3)	5.4 (4.5–6.5)

Only data of stem-cup combinations that did not mix different manufacturers are displayed. The number of implants and revision risk at 5- and 10-year follow-up are presented

NRJ National Joint Registry of England, Wales, and Northern Ireland, *AOANJRR* Australian Orthopedic Association National Joint Replacement Registry

4.2 Epidemiology

The prevalence of hip revision surgery has increased due to the growing number of patients with a total hip arthroplasty. The burden of revision total hip replacement has remained constant despite advances in implant design and the diminished wear of new polyethylenes. Hospital stay, inpatient complications, and mortality have diminished in recent years. However, the rate of perioperative complications in revision surgery has grown. According to NIS data, the proportion of primary and revision hip arthroplasties has remained constant between 2006 and 2010 (85% primary THA versus 15% revision THA). Revision arthroplasty was performed more frequently in teaching hospitals with lower complication rates but with longer lengths of stay [24]. However, in more recent years, there has been a gradual increase in the number of patients revised due to infection or for recurrent dislocation [25].

Differences in clinical practice between individual Scandinavian countries have been studied. Fifteen-year survivorship in Norway, Sweden, Finland, and Denmark was compared. There were important differences in survivorship values between the four countries, with a lower revision risk in Sweden [17]. Comparing geographically distant countries such as the USA, Sweden, and Australia, the data has also shown a higher survival rate in Sweden, with lower BMI and ASA values for the patients who underwent a THA for OA. With regard to implant choice, cemented fixation, metal on conventional polyethylene, and smaller head sizes were more prevalent in Sweden than in the USA or Australia [10].

There are racial disparities in the access to revision surgery among the African-American population, these having fewer opportunities to undergo a primary or a revision hip arthroplasty [9]. This disparity has also been evidenced by higher complication and readmission rates following joint arthroplasties in African-American, Asian, Hispanic, and mixed-race patients in American hospitals [26].

Over time the range of causes for revision has changed. In 1999, in the Swedish Registry, aseptic loosening accounted for almost 70% of the revisions. In 2017, loosening still remained the primary cause but with a smaller proportion. Infection is the second largest cause, accounting for one-quarter of revisions [15]. In the USA and Australia, dislocation during the first 5 years of follow-up has become the most frequent reason for revision. It must be noted, however, that osteolysis is reported separately from loosening in those series, which may lead to underreporting of aseptic loosening [9, 21]. Countries where cemented fixation was more prevalent showed a lower revision rate for periprosthetic fractures [21, 27]. In the NJR, due to the use of metal on metal bearing in the UK, 16.7% of the revisions were for adverse soft tissue reactions and particular debris [27]. Table 4.4 reports most prevalent revision cause in the different registries.

Patient age affects the cause of revision. Older patients are less likely to be revised. They may not survive long enough to be revised, and they present inferior activity levels and wear than younger patients. In younger patients, acetabular or femoral loosening and polyethylene wear are the major causes for revision [4, 15]. The Australian Registry in its latest report analyzes the group of patients over the age of 80. Although 30-day and late mortality were higher than in younger patients, 80% of the THA in the 80–90-year-old group and 60% of the THA in the >90-year-old group are still alive at 5 years

Table 4.4 Most frequent revision causes in the hip registries of Sweden, Australia and the Registry of England, Wales, Northern Ireland and the Isle of Mann

Registry	Year	Aseptic loosening	Instability	Infection	Periprosthetic fracture
Sweden (SHAR)	2017	44.6%	13.6%	25.6%	10.5%
Australia (AOANJRR)	2018	25%	21.1%	18%	20.3%
England, Wales, North Ireland, Man (NJR)	2018	24.2%	16.8%	14%	13.4%

SHAR Swedish Hip Arthroplasty Registry, *AOANJRR* Australian Orthopedic Association National Joint Replacement Registry, *NRJ* National Joint Registry of England, Wales, and Northern Ireland

follow-up. Fracture is the main reason for revision in that age group and is associated with cementless fixation [21].

4.3 Causes of Revision

4.3.1 Aseptic Loosening

Persistent pain is the reason for revision in most patients. Pain is rarely reported as the sole cause of revision in arthroplasties. It is generally associated with another cause such as loosening or infection [27]. Aseptic loosening is the primary cause for revision in most of the registries and THA cohorts. Loosening remains a concern, there being factors related to implant design and wear, together with factors related to patient susceptibility (Figs. 4.1 and 4.2) [4, 9, 10, 13–16, 18, 20, 21, 27, 28].

Both cemented and uncemented implants loosen. The outcome with respect to fixation method varies with age. In patients under 65 years of age, cementless fixation provides equal results. In older patients, cementless fixation has a higher revision rate than hybrid or cemented fixation [21].

Male sex and a high activity level [University of California, Los Angeles (UCLA), score >9] are risk factors for aseptic loosening. Patients should be encouraged not to practice contact sports [8]. A higher level of activity would accelerate the development of wear particles. These particles generate an inflammatory response with osteoclast activation, bone resorption, and osteolysis [29]. Prostheses in young patients are mainly revised for femoral or acetabular loosening and wear [4].

When polyethylene wear rates exceed 0.1–0.2 per year, the risk of periprosthetic osteolysis and its related complications increase. Conventional

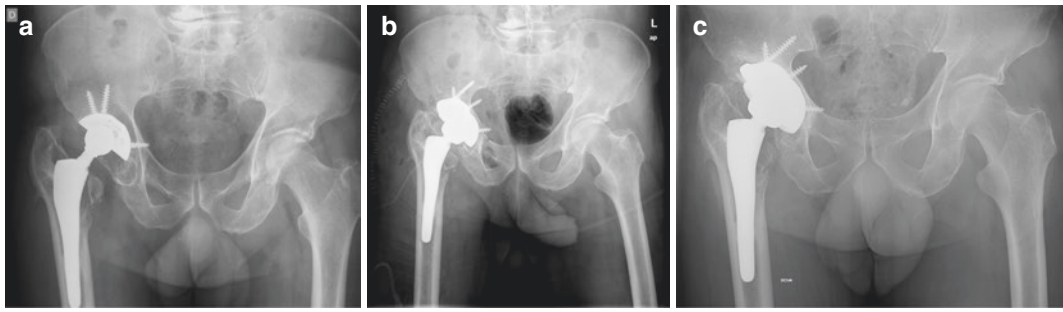

Fig. 4.1 Fifty-eight-year-old man presented groin pain 18 years following uncemented THA. Loosening of the acetabular component with a large area of osteolysis (**a**). Revised with a trabecular metal augment and a trabecular metal cup with a good restoration of the hip center (**b**). Two-year follow-up plain X-ray with good integration of the prosthesis (**c**)

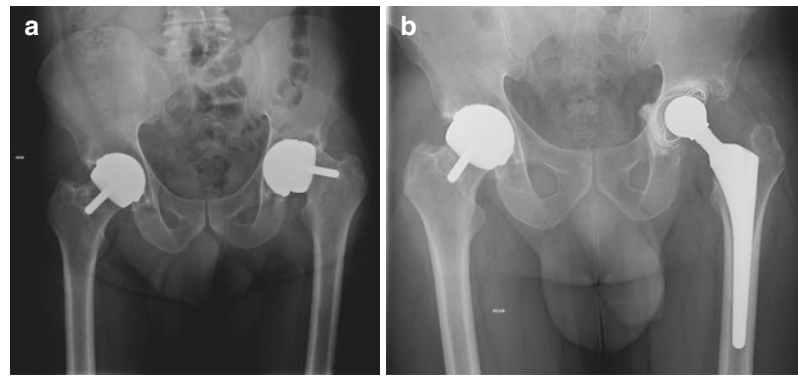

Fig. 4.2 Radiograph of a resurfacing arthroplasty at 7 years postoperatively, showing loosening of the femoral component (**a**). The surgery showed important soft tissue and bone resorption due to a pseudotumor around the joint requiring impacted bone grafting and a cemented cup (**b**)

polyethylene presented wear revision rates of around 12–14% at 15 years follow-up [30]. In 2001, highly cross-linked polyethylene (HXLPE) was introduced into orthopedic practice. Its use has reduced wear rates and the risk of revision for aseptic loosening, especially in younger patients [4, 31]. Bryan et al. compared traditional ultrahigh-molecular-weight polyethylene (UHMWPE) with HXLPE, at 15 years follow-up. In the non-HXLPE, they reported 0.23 mm/year of wear with 70% of osteolysis and 10% of wear for revisions. On the other hand, there was no wear-related revision detectable or osteolysis in the HXLPE group [4, 32]. However, nowadays, despite the improved wear-reducing properties of modern HXLPE, osteolysis generated by polyethylene debris particles remains the main cause of loosening and the reason for revision hip arthroplasty.

4.3.2 Instability

Instability has become the principal cause of revision in the USA [27]. The incidence of dislocation after revision surgery is higher than in primary surgery [7, 33–35]. Dislocation is multifactorial and is associated with implant positioning, approach, soft tissue balance, and patient-related factors (gender, diagnosis, alcoholism, neuromuscular problems) (Fig. 4.3). Current trends to prevent dislocation include the use of a direct anterior approach, a larger femoral head, or dual-mobility components [7].

Dislocation is more frequent in older patients due to poorer muscular balance and deteriorated soft tissues. When dislocation occurs closer to the primary THA, there is a higher success rate with conservative treatment. Late dislocations usually become recurrent and require revision surgery [36].

The direct anterior approach (DAA) has gained popularity in the last decade. DAA offers earlier functional recovery with lower rates of leg length discrepancy and lower postoperative dislocations [37]. However, DAA requires a learning curve of about 50 cases, and both intraoperative and postoperative complications are not infrequent [38]. There are concerns relating to the association between DAA and higher revision rates of the femoral component [39].

Bigger heads provide a bigger head-neck ratio and a greater jump distance, hence preventing head dislocation. The problems of a larger head are the increased forces in the trunnion and higher volumetric wear [40]. However, 32-mm head arthroplasties have reduced the revision risk compared to 28-mm head THA due to a lower incidence of dislocation. No differences in the dislocation rate were seen between 32- and 36-mm heads. Furthermore, the risk of revision for all reasons is higher in metal on polyethylene when a 36-mm head is employed [41].

Dual-mobility cups prevent dislocation in primary and revision THA. Developed in France, its use is popular in revision surgery, being used in two-thirds of hip revisions. In the USA, according to the American Joint Replacement Registry (AJRR), dual mobility is employed in 7% of primary THA and in 20% of revisions [28]. In a systematic review of studies employing dual-mobility constructs, during primary procedures, the odds ratio for dislocation was four times greater in conventional THA compared to dual mobility (95% CI 1.7–9.7, $p < 0.01$). In revision surgery, the risk of dislocation was three times higher in the conventional group (95% CI 2–6.56, $p < 0.01$) [35].

Patients operated on for lumbar spine fusion present a higher dislocation risk of around 4% and a 7.5–10.6% revision rate due to instability. The sequence has an impact on dislocation and the need for revision surgery. Patients with a previous fusion had a 46% higher dislocation risk than patients who received a lumbar fusion 5 years after a THA [42].

4.3.3 Periprosthetic Fracture

Periprosthetic femoral fracture is the third major cause for revision surgery, with an incidence ranging from 0.1% to 2.1% (Fig. 4.4) [43]. Aging populations and an increased number of THAs are increasing this incidence. The Vancouver classification assesses stem stability and fracture pattern [44]. Some registries do not include periprosthetic fractures managed with open reduction

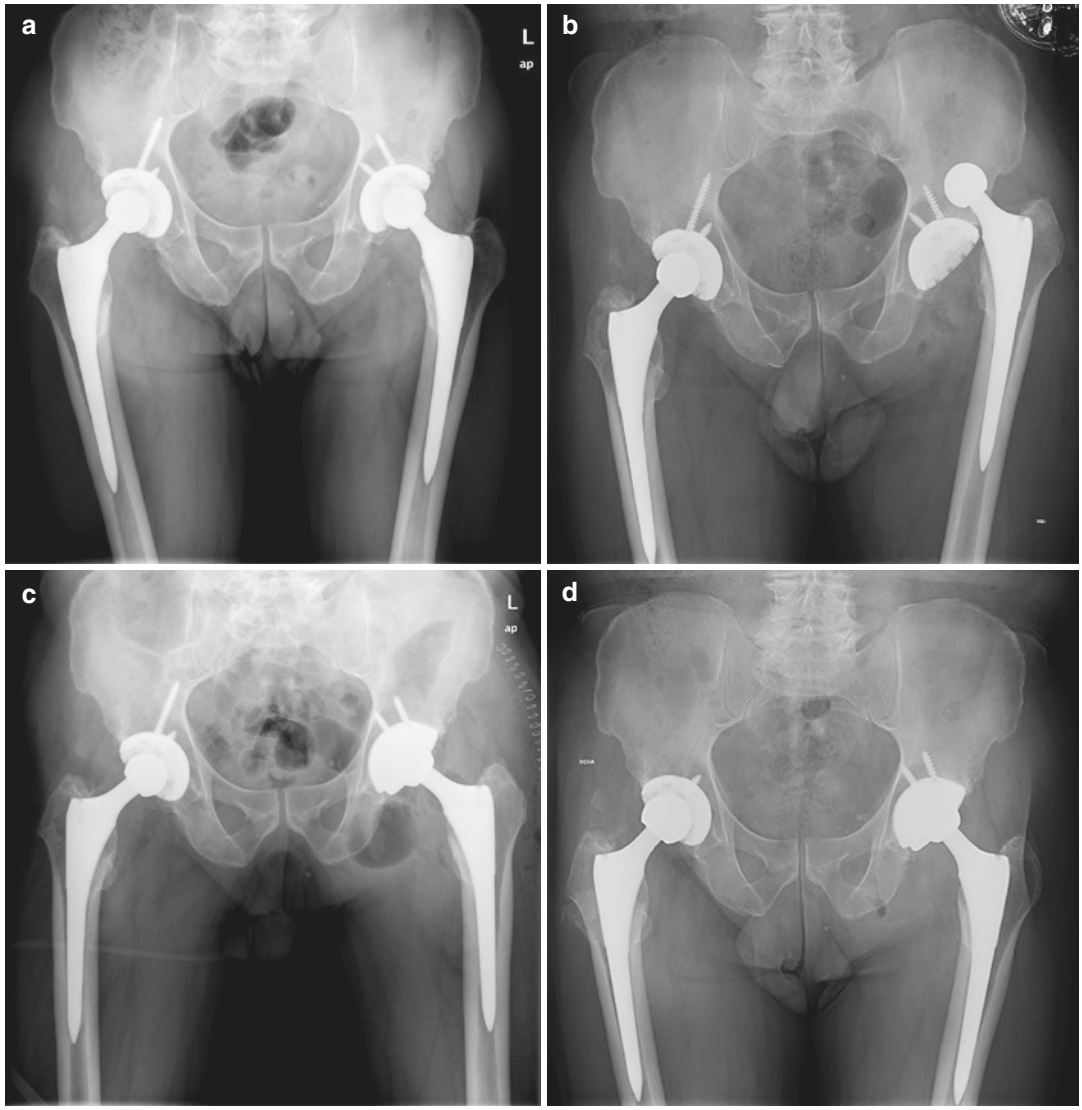

Fig. 4.3 Sixty-seven-year-old male patient who underwent bilateral THA for primary OA (**a**). The patient suffered a left hip dislocation 7 years from the primary surgery managed with closed reduction (**b**). The patient presented two recurrent dislocations. The acetabular component was revised to a dual mobility construct (**c**). Two-year follow up X-ray of the revision arthroplasty (**d**)

and internal fixation (ORIF), which do not require revision of the femoral component, so they may be underreported in these registries [43].

Some risk factors for periprosthetic fracture are patient-related, such as age, sex, poor bone quality, activity level, and a previous diagnosis of femoral neck fracture or inflammatory arthropathy. Other factors are related to surgery (femoral cortical defects, previous hardware removal, varus position of the stem, etc.) [45]. The type of implant plays a crucial role. Uncemented implants present a higher incidence of periprosthetic fractures, especially those designs with single- or double-wedge morphology. In cemented implants, fractures were more common in "force-closed" stems such as the Exeter (Stryker) stem than with "shape-closed" stems such the SPII Lubinus (Waldemar Link) [46, 47].

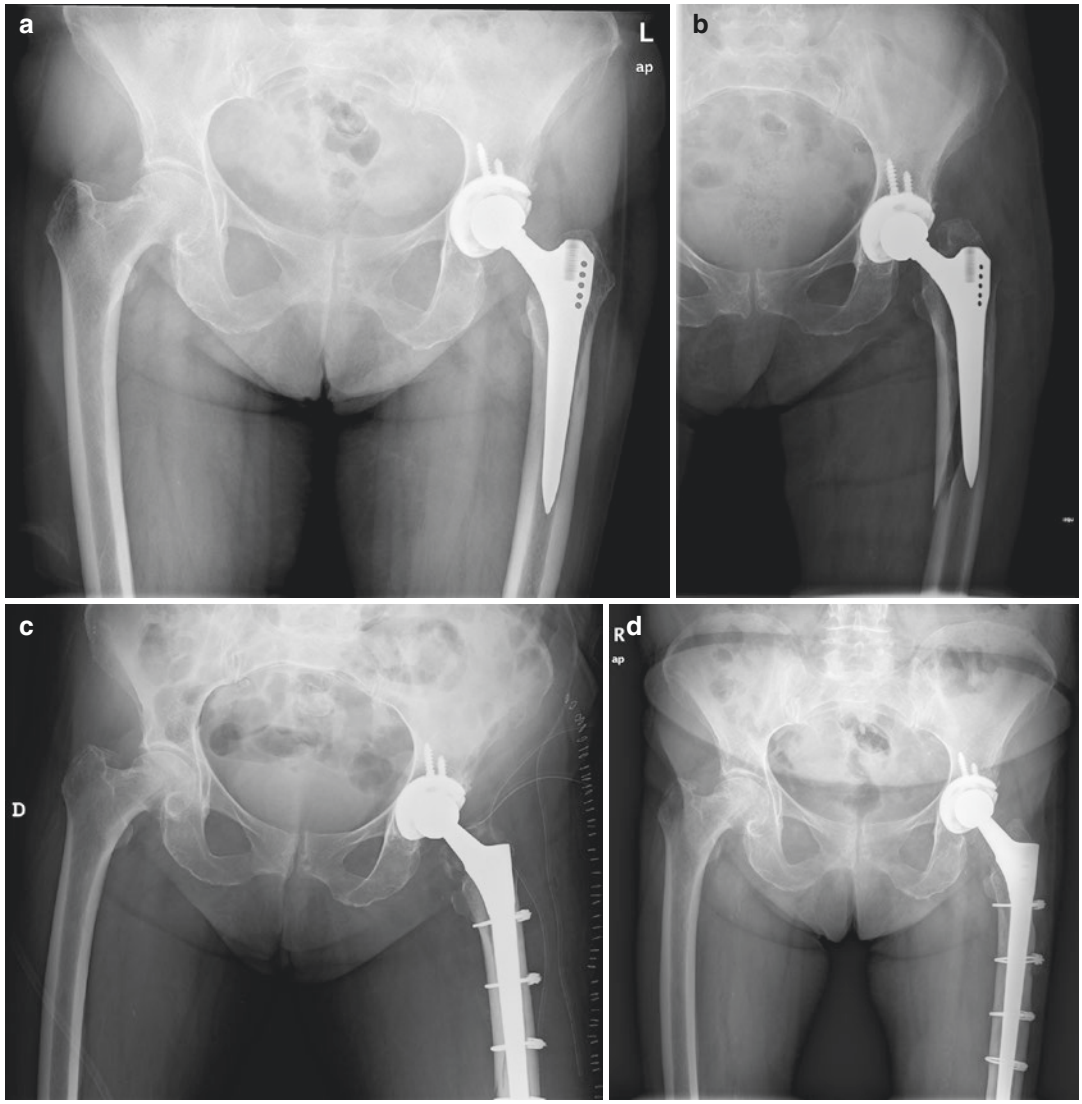

Fig. 4.4 Sixty-eight-year-old woman, with a left uncemented THA for primary OA (**a**). Sustained a B2 periprosthetic femoral fracture with stem subsidence (**b**). Revised with a long uncemented diaphyseal fixation stem (**c**). Three years postoperatively with union of the fracture and good clinical and radiologic result (**d**)

A correct classification, with a correct differentiation between B1 and B2 fractures, is critical. Medical records of previous thigh pain, follow-up x-rays, and computed tomography (CT) CT scans are often required [48]. The Swedish Registry reported a high failure of supposed B1 fractures managed with ORIF. Fractures managed with a single plate or cerclage wires accounted for between 34% and 44% of failures and need for reoperation [49]. Corten et al. recommend testing stem stability intraoperatively before trying to fix the fracture [50]. Stem revision provides better functional results due to earlier mobilization and weight bearing compared with ORIF. Surgeons with extensive management skills in traumatology and hip revision procedures obtain better results in these complex cases [51].

4.3.4 Infection

Infection is the most devastating complication of a total hip replacement (Fig. 4.5). Infection rates are between 0.7% and 3% after a primary THA [52]. It is a growing cause for hip revision, accounting for between 14% and 24% of these [9, 15, 27]. Patient-related risk factors for

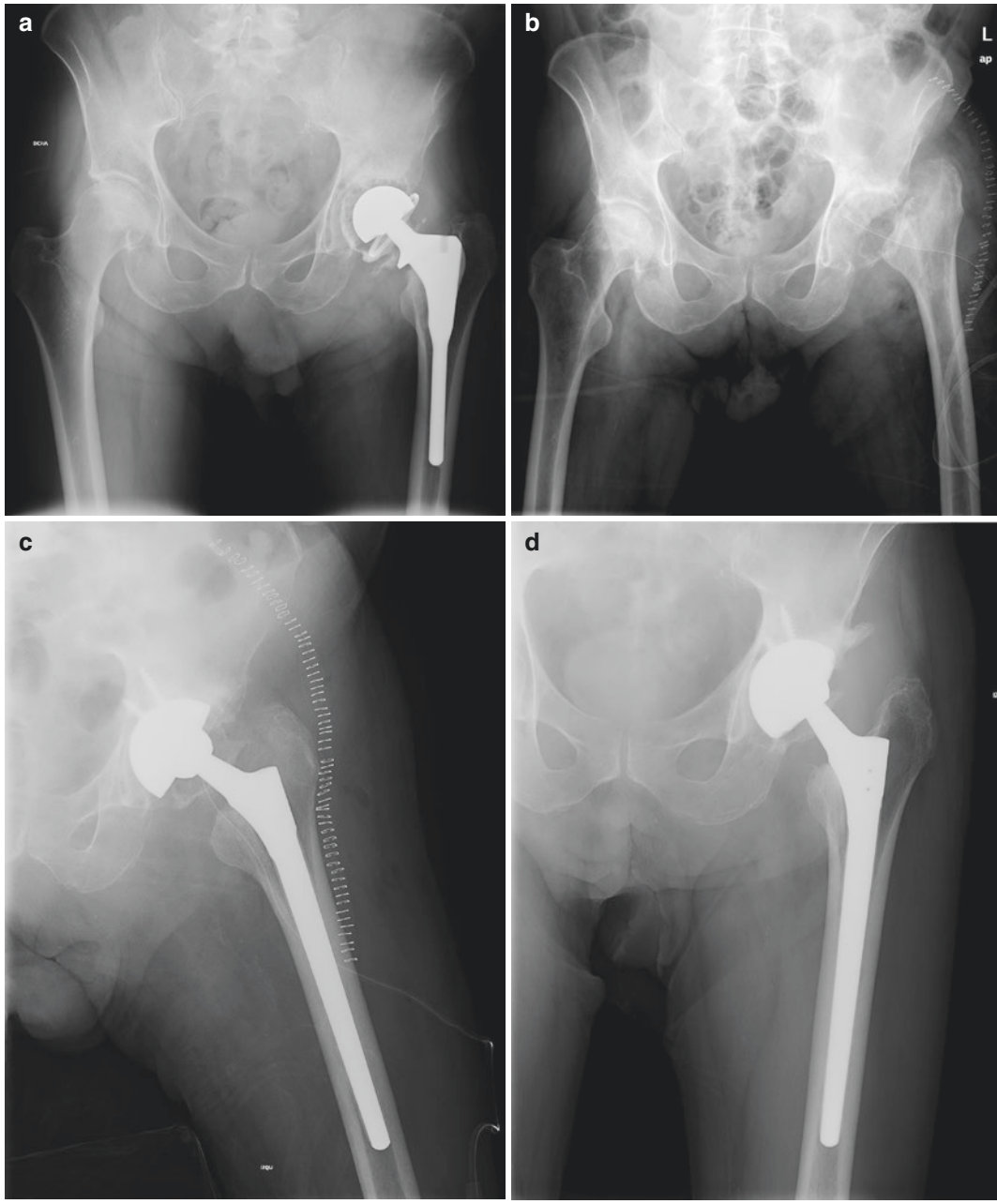

Fig. 4.5 Seventy-three-year-old male patient, revised with a cemented constrained liner for recurrent dislocation (**a**). Presented a periprosthetic joint infection caused by *Staph epidermidis*. Managed with a two-stage revision surgery, without spacer (**b**). Revised with a dual-mobility acetabular component and an uncemented revision stem (**c**). One-year follow-up X-ray after the revision surgery (**d**)

infection are numerous and include the presence of inflammatory conditions, obesity, comorbidities that cause immunosuppression, a history of intravenous drug abuse, skin problems, and previous infection of the surgical site. Risk factors related to surgery include prolonged surgical times and the need for multiple blood transfusions. The Musculoskeletal Infection Society has developed major and minor criteria for the diagnosis of periprosthetic joint infection (PJI) [53].

A correct diagnosis of PJI is mandatory in order to ensure an effective treatment. Management of this complication is complex and requires a multidisciplinary approach. Pain and stiffness are the most frequent patient-reported symptoms. In the physical exam, excessive warmth, redness, swelling, and effusion in the hip region or the presence of a sinus tract indicate PJI. Radiological evidence of PJI includes progressive radiolucent lines with bone resorption, calcifications, or early loosening. Erythrocyte sedimentation rate (ESR) and serum C-reactive protein (CRP) levels are the most common lab tests used to rule out infection prior to a revision surgery. Both tests have a high sensitivity and specificity. An ESR of under 30 mm/h or a CRP below 10 mg/L, in the absence of infection-specific clinical features, can rule out infection [54]. Selective hip aspiration can be carried out if both CRP and ESR levels are elevated, though this may yield false-negative results [33]. Multiple intraoperative cultures are also required if a possible PJI is suspected [33]. Leucocyte esterase has proven its sensibility and efficacy in detecting synovial fluid infection, thus enabling an intraoperative diagnosis [55].

Two-stage revision surgery is the standard of care for PJI. It requires a prolonged hospitalization period with elevated costs, multiple operations, and impairs patient function. However, an infected THA can be managed successfully with a single-stage revision; but some premises are required: good patient conditions, an absence of comorbidities or immunosuppression, adequate soft tissues, and bone stock. The infection must not be polymicrobial, and a known pathogen must exist, together with a good antibiotic sensitivity [56].

Two-stage revision has traditionally been the preferred method of managing PJI with success rates of around 90% [57]. Several centers advocate single-stage revision, which carries inferior costs, is less traumatic for the patient, and provides better functional outcomes [56]. Between 1979 and 2015, 80% of the revisions performed in Sweden for infection were two-stage procedures. However, the percentage of single-stage revisions increased in the last 5 years. There was no difference in the risk of re-revision due to infection for any cause between one-stage and two-stage revisions [58].

Hip abductor function deteriorates after two-stage revision. There is a 10% dislocation risk at 5 years following two-stage revision. A trochanter or abductor deficiency generates a significantly higher dislocation risk, especially if a megaprosthesis is used to reconstruct the proximal femur. When a dual-mobility construct is employed, the risk of hip dislocation is over three times lower [34].

4.3.5 Revision of Metal on Metal Hip Arthroplasty

Metal on metal (MoM) was thought to be an effective bearing surface with reduced wear. It allowed for larger-sized femoral heads with a greater physiological range of motion and lower dislocation risk. Metal-on-metal arthroplasty peaked in the year 2008. High failure rates were reported thereafter, and the threshold changed to conventional bearing couples. Registry data from the Australian Orthopedic Association National Joint Replacement Registry (AOANJRR), and confirmed by the NJR, highlighted the elevated revision rates of the ASR resurfacing and ASR XL acetabular system implants (DePuy Orthopedics). This led to a recall of the ASR implants [19, 21, 27].

Local adverse reaction to metal debris (ARMD) is one of the reasons for revising a metal-on-metal arthroplasty. Similar secondary adverse effects have also been reported with metal modular junctions in modular prostheses. Cobalt (Co) and chrome (Cr) ions may be generated not only in the metal-on-metal bearing but also in the modular

parts, generating significantly higher ion levels [59]. Patients with MoM should be followed-up and, if the hip becomes symptomatic, it must be studied. Metal ion serum levels need to be measured. The cutoff level of 7 parts per billion or μg/L for cobalt or chromium constitutes the need to perform advanced imaging studies. In the presence of a painful MoM arthroplasty or a modular stem, magnetic resonance imaging (MRI) can predict a pathological soft tissue response. MRI can distinguish synovial response in THA, with a strong correlation with wear, particle generation, corrosion, and fretting [60]. Pseudotumors can destroy the joint capsule and abductor mechanism, compromising functional outcome after the revision surgery [61].

The corrosion at the junction of Co-Cr heads on titanium stems has also been associated with ARMD. Modern tapered designs tend to be shorter to improve the head-neck ratio. This reduces its surface and increases stress forces and corrosion, especially with large Co-Cr heads [62]. Corrosion with modular neck stem designs has also been reported [63]. Symptoms may include unexplained pain and instability. The differential diagnosis needs to discard infection [40]. The presence of elevated serum ion levels with higher levels of cobalt than chromium is characteristic. This disproportion is helpful in the diagnosis of fretting corrosion in the presence of an unexplained painful arthroplasty [64].

4.3.6 Material Failure

Earlier cast stems were susceptible to fatigue failure with long follow-ups. Nowadays, stem fracture is extremely rare with current forged designs made of forged cobalt, chromium, and titanium alloys. Nevertheless, breakage of some modern-day, modular long varus necks has been reported. In the Swedish registry, 140 stem fractures were reported between 1999 and 2017 out of some 280,000 arthroplasties. Most of these implants were the smallest available size, and their use should be avoided in active patients [15]. In revision surgery, limited bone stock and distal fixation increase stress forces in long revision stems. Modular revision stems have shown failures at the junction between the distal and metaphyseal parts [65].

Ceramic-on-ceramic bearing reduces wear in young, active patients. However, fractures of ceramic liners and femoral heads have been reported (Fig. 4.6). Third-generation ceramics have reduced their fracture rate to 0.004%. The use of short-neck femoral heads and incomplete seating of the ceramic liner are known to be risk factors for ceramic fracture [66]. There are no clinical guidelines for managing ceramic component fracture. After a ceramic head fracture, if the taper is badly damaged, the stem needs to be revised. If the taper is in good condition, a new ceramic head with a metal adapter may be used. Following a

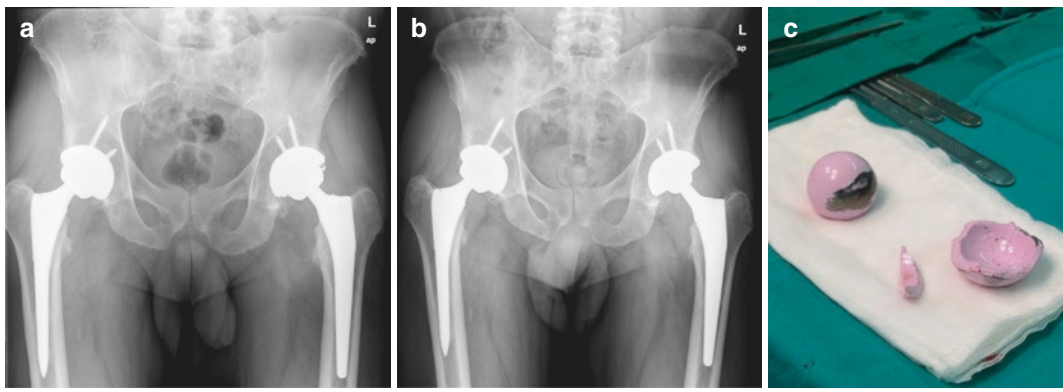

Fig. 4.6 Anteroposterior radiograph of a 62-year-old patient, who had bilateral THA with 36-mm femoral head ceramic on ceramic THA. Ten months after the surgery (**a**), the patient suffered a rupture of the ceramic liner in the left hip due to incomplete seating (**b**). The hip was revised to a new ceramic liner for 28-mm head size (**c**)

ceramic liner fracture, the bearing can be revised to a new ceramic liner and head [67].

4.4 Multiple Revisions

Although revision techniques and implants have improved in recent years, revision THAs present a higher failure rate. The risk of revising a revision arthroplasty is 4.3 times higher compared with a primary THA, and, if we analyze second-time revisions, it is 6.6 times higher than the primary operation. The risk of failure is also higher in men than in women [15]. In a cohort of 548 THAs in patients under the age of 35, 128 hips (23%) required revision surgery at a mean of 10 years after the index procedure. Thirty-one (28.7%) of these prostheses required a re-revision after only a further 4.3 years, the primary reason for this being aseptic loosening [4]. Out of 2589 aseptic revisions performed at a single institution, with a mean follow-up of 6 years, 211 required a new revision. The principal cause was instability (52%), followed by aseptic loosening (20%). New materials employed in revision surgery have improved fixation with limited bone stock. Thus, aseptic loosening has become less frequent after revision surgery [6].

The etiology of the revision affects patient life expectancy. Prostheses operated on for aseptic loosening present longer survivorship than patients revised for periprosthetic fracture, dislocation or infection [3]. Surgeons should analyze registry data and different revision causes in order to prevent them.

4.5 Conclusions

The age at which a THA is indicated affects its survivorship. Hip replacements are more often used in younger patients with a different diagnosis from primary OA. Deformities, diagnosis, and higher activity levels affect the prognosis of these arthroplasties. Despite improved wear-reducing properties and designs, any THA would require to be revised given enough follow-up. Registries provide valuable information about hip survivorship; related to different diagnosis, comorbidities, approaches, implant designs, etc.

The epidemiology of hip revision has changed in recent years. Aseptic loosening still remains the leading cause for revision, but, meanwhile, the rate of revision for dislocation, infection, or fracture has increased. Dual-mobility constructs reduce dislocation rate, but currently there are no published long-term results with these designs. Local adverse reactions to metal debris and the inferior results of MoM implants have reduced their use. Revision surgery provides inferior survivorship and clinical results than primary THA. New revision techniques allow a durable fixation to be obtained in the presence of limited bone stock. However, instability and infection remain ongoing, unsolved problems.

References

1. Evans JT, Evans JP, Walker RW, Blom AW, Whitehouse MR, Sayers A. How long does a hip replacement last? A systematic review and meta-analysis of case series and national registry reports with more than 15 years of follow-up. Lancet Lond Engl. 2019;393(10172):647–54.
2. NICE. Overview | Total hip replacement and resurfacing arthroplasty for end-stage arthritis of the hip | Guidance | NICE. London: NICE; 2019. [cited 2019 Apr 27]. Available from https://www.nice.org.uk/guidance/ta304.
3. Cnudde P, Bülow E, Nemes S, Tyson Y, Mohaddes M, Rolfson O. Association between patient survival following reoperation after total hip replacement and the reason for reoperation: an analysis of 9,926 patients in the Swedish Hip Arthroplasty Register. Acta Orthop. 2019;90:226–30.
4. Kahlenberg CA, Swarup I, Krell EC, Heinz N, Figgie MP. Causes of revision in young patients undergoing total hip arthroplasty. J Arthroplasty. 2019;34:1435. S0883540319302372 [pii]
5. Kurtz S. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am. 2007;89(4):780.
6. Goldman AH, Sierra RJ, Trousdale RT, Lewallen DG, Berry DJ, Abdel MP. The Lawrence D. Dorr surgical techniques & technologies award: why are contemporary revision total hip arthroplasties failing? An Analysis of 2500 Cases. J Arthroplasty. 2019;34:S11.
7. Springer BD, Fehring TK, Griffin WL, Odum SM, Masonis JL. Why revision total hip arthroplasty fails. Clin Orthop. 2009;467(1):166–73.

8. Cherian JJ, Jauregui JJ, Banerjee S, Pierce T, Mont MA. What host factors affect aseptic loosening after THA and TKA? Clin Orthop Relat Res. 2015;473(8):2700–9.
9. Gwam CU, Mistry JB, Mohamed NS, Thomas M, Bigart KC, Mont MA, et al. Current epidemiology of revision total hip arthroplasty in the United States: national inpatient sample 2009 to 2013. J Arthroplasty. 2017;32(7):2088–92.
10. Paxton EW, Cafri G, Nemes S, Lorimer M, Kärrholm J, Malchau H, et al. An international comparison of THA patients, implants, techniques, and survivorship in Sweden, Australia, and the United States. Acta Orthop. 2019;90(2):148–52.
11. Berry DJ, Harmsen WS, Cabanela ME, Morrey BF. Twenty-five-year survivorship of two thousand consecutive primary Charnley total hip replacements: factors affecting survivorship of acetabular and femoral components. J Bone Joint Surg Am. 2002;84-A(2):171–7.
12. Labek G, Neumann D, Agreiter M, Schuh R, Böhler N. Impact of implant developers on published outcome and reproducibility of cohort-based clinical studies in arthroplasty. J Bone Joint Surg Am. 2011;93(Suppl 3):55–61.
13. Lübbeke A, Silman AJ, Barea C, Prieto-Alhambra D, Carr AJ. Mapping existing hip and knee replacement registries in Europe. Health Policy. 2018;122(5):548–57.
14. Danish Orthopaedic Society. Annual reports – The Danish Hip Arthroplasty register. Lyngskrænten: Danish Orthopaedic Society; 2019. [cited 2019 Apr 29]. Available from http://danskhoftealloplastikregister.dk/en/publications/annual-reports/.
15. Svenska Höftprotesregistret. Annual reports. Göteborg: Svenska Höftprotesregistret; 2019. [cited 2019 Apr 29]. Available from https://shpr.registercentrum.se/shar-in-english/annual-reports/p/rkeyyeElz.
16. Hughes RE, Batra A, Hallstrom BR. Arthroplasty registries around the world: valuable sources of hip implant revision risk data. Curr Rev Musculoskelet Med. 2017;10(2):240–52.
17. Mäkelä KT, Matilainen M, Pulkkinen P, Fenstad AM, Havelin LI, Engesaeter L, et al. Countrywise results of total hip replacement. An analysis of 438,733 hips based on the Nordic Arthroplasty Register Association database. Acta Orthop. 2014;85(2):107–16.
18. Finnish Arthroplasty Registry (FAR). Annual reports. Helsinki: FAR; 2019. [cited 2019 Apr 29]. Available from https://thl.fi/far/#index.
19. Delaunay C. Registries in orthopaedics. Orthop Traumatol Surg Res. 2015;101(1):S69–75.
20. Nasjonalt Servicemiljø for Medisinske Kvalitetsregistre. Annual reports. Trondheim: Nasjonalt Servicemiljø for Medisinske Kvalitetsregistre; 2019. [cited 2019 Apr 29]. Available from https://www.kvalitetsregistre.no/resultater.
21. Australian Orthopaedic Association National Joint Replacement Registry. Annual reports. Adelaide, SA: AOANJRR; 2019. [cited 2019 Apr 29]. Available from https://aoanjrr.sahmri.com/.
22. Bayliss LE, Culliford D, Monk AP, Glyn-Jones S, Prieto-Alhambra D, Judge A, et al. The effect of patient age at intervention on risk of implant revision after total replacement of the hip or knee: a population-based cohort study. Lancet Lond Engl. 2017;389(10077):1424–30.
23. Anand R, Graves SE, de Steiger RN, Davidson DC, Ryan P, Miller LN, et al. What is the benefit of introducing new hip and knee prostheses? J Bone Joint Surg Am. 2011;93(Suppl 3):51–4.
24. Kowalik TD, DeHart M, Gehling H, Gehling P, Schabel K, Duwelius P, et al. The epidemiology of primary and revision total hip arthroplasty in teaching and nonteaching hospitals in the United States. J Am Acad Orthop Surg. 2016;24(6):393–8.
25. Cnudde P, Nemes S, Bülow E, Timperley J, Malchau H, Kärrholm J, et al. Trends in hip replacements between 1999 and 2012 in Sweden. J Orthop Res. 2018;36:432. [cited 2019 May 2]. Available from http://doi.wiley.com/10.1002/jor.23711
26. Pandya NK, Wustrack R, Metz L, Ward D. Current concepts in orthopaedic care disparities. J Am Acad Orthop Surg. 2018;26(23):823–32.
27. NJR. 15th Annual report 2018. Hemel Hempstead: NJR; 2018. Available from:http://www.njrreports.org.uk/.
28. Heckmann N, Ihn H, Stefl M, Etkin CD, Springer BD, Berry DJ, et al. Early results from the American joint replacement registry: a comparison with other national registries. J Arthroplasty. 2019;34:S125. S0883540318312282 [pii]
29. Jiang Y, Jia T, Wooley PH, Yang S-Y. Current research in the pathogenesis of aseptic implant loosening associated with particulate wear debris. Acta Orthop Belg. 2013;79(1):1–9.
30. Stambough JB, Rames RD, Pashos GE, Maloney WJ, Martell JM, Clohisy JC. Conventional polyethylene in total hip arthroplasty in young patients: survivorship, wear analysis, and clinical outcomes between 15 and 20 years. J Arthroplasty. 2018;33(12):3712–8.
31. Ranawat CS, Ranawat AS, Ramteke AA, Nawabi D, Meftah M. Long-term results of a first-generation annealed highly cross-linked polyethylene in young, active patients. Orthopedics. 2016;39(2):e225–9.
32. Bryan AJ, Calkins TE, Karas V, Culvern C, Nam D, Della Valle CJ. Primary total hip arthroplasty in patients less than 50 years of age at a mean of 16 years: highly crosslinked polyethylene significantly reduces the risk of revision. J Arthroplasty. 2019;34:S238. S0883540319301810 [pii]
33. Kuzyk PRT, Dhotar HS, Sternheim A, Gross AE, Safir O, Backstein D. Two-stage revision arthroplasty for management of chronic periprosthetic hip and knee infection: techniques, controversies, and outcomes. J Am Acad Orthop Surg. 2014;22(3):153–64.
34. McAlister IP, Perry KI, Mara KC, Hanssen AD, Berry DJ, Abdel MP. Two-stage revision of total hip arthro-

plasty for infection is associated with a high rate of dislocation. J Bone Joint Surg Am. 2019;101(4):322–9.
35. Reina N, Pareek A, Krych AJ, Pagnano MW, Berry DJ, Abdel MP. Dual-mobility constructs in primary and revision total hip arthroplasty: a systematic review of comparative studies. J Arthroplasty. 2019;34(3):594–603.
36. Norambuena GA, Wyles CC, Van Demark RE, Trousdale RT. Effect of dislocation timing following primary total hip arthroplasty on the risk of redislocation and revision. Hip Int J Clin Exp Res Hip Pathol Ther. 2019;11:1120700019828144.
37. Lovell TP. Single-incision direct anterior approach for total hip arthroplasty using a standard operating table. J Arthroplasty. 2008;23(7 Suppl):64–8.
38. Berend KR, Mirza AJ, Morris MJ, Lombardi AV. Risk of periprosthetic fractures with direct anterior primary total hip arthroplasty. J Arthroplasty. 2016;31(10):2295–8.
39. Meneghini RM, Elston AS, Chen AF, Kheir MM, Fehring TK, Springer BD. Direct anterior approach: risk factor for early femoral failure of cementless total hip arthroplasty. J Bone Joint Surg. 2017;99(2):99–105.
40. Carli A, Politis A, Zukor D, Huk O, Antoniou J. Clinically significant corrosion at the head-neck taper interface in total hip arthroplasty: a systematic review and case series. Hip Int. 2015;25(1):7–14.
41. Tsikandylakis G, Kärrholm J, Hailer NP, Eskelinen A, Mäkelä KT, Hallan G, et al. No increase in survival for 36-mm versus 32-mm femoral heads in metal-on-polyethylene THA: a registry study. Clin Orthop. 2018;476(12):2367–78.
42. Malkani AL, Himschoot KJ, Ong KL, Lau EC, Baykal D, Dimar JR, et al. Does timing of primary total hip arthroplasty prior to or after lumbar spine fusion have an effect on dislocation and revision rates? J Arthroplasty. 2019;34(5):907–11.
43. Lindahl H, Malchau H, Herberts P, Garellick G. Periprosthetic femoral fractures. J Arthroplasty. 2005;20(7):857–65.
44. Duncan CP, Masri BA. Fractures of the femur after hip replacement. Instr Course Lect. 1995;44:293–304.
45. Kavanagh BF. Femoral fractures associated with total hip arthroplasty. Orthop Clin North Am. 1992;23(2):249–57.
46. Chatziagorou G, Lindahl H, Kärrholm J. The design of the cemented stem influences the risk of Vancouver type B fractures, but not of type C: an analysis of 82,837 Lubinus SPII and Exeter Polished stems. Acta Orthop. 2019;90(2):135–42.
47. Carli AV, Negus JJ, Haddad FS. Periprosthetic femoral fractures and trying to avoid them: what is the contribution of femoral component design to the increased risk of periprosthetic femoral fracture? Bone Joint J. 2017;99-B(1 Supple A):50–9.
48. Pavone V, de Cristo C, Di Stefano A, Costarella L, Testa G, Sessa G. Periprosthetic femoral fractures after total hip arthroplasty: an algorithm of treatment. Injury. 2019;50:S45.
49. Lindahl H, Malchau H, Odén A, Garellick G. Risk factors for failure after treatment of a periprosthetic fracture of the femur. J Bone Joint Surg Br. 2006;88-B(1):26–30.
50. Corten K, Vanrykel F, Bellemans J, Frederix PR, Simon J-P, Broos PLO. An algorithm for the surgical treatment of periprosthetic fractures of the femur around a well-fixed femoral component. J Bone Joint Surg Br. 2009;91-B(11):1424–30.
51. Giaretta S, Momoli A, Porcelli G, Micheloni GM. Diagnosis and management of periprosthetic femoral fractures after hip arthroplasty. Injury. 2019;50:S29. S0020138319300531 [pii]
52. Ong KL, Kurtz SM, Lau E, Bozic KJ, Berry DJ, Parvizi J. Prosthetic joint infection risk after total hip arthroplasty in the Medicare population. J Arthroplasty. 2009;24(6 Suppl):105–9.
53. Parvizi J, Zmistowski B, Berbari EF, Bauer TW, Springer BD, Della Valle CJ, et al. New definition for periprosthetic joint infection: from the Workgroup of the Musculoskeletal Infection Society. Clin Orthop. 2011;469(11):2992–4.
54. Huerfano E, Bautista M, Huerfano M, Bonilla G, Llinas A. Screening for infection before revision hip arthroplasty: a meta-analysis of likelihood ratios of erythrocyte sedimentation rate and serum C-reactive protein levels. J Am Acad Orthop Surg. 2017;25(12):809–17.
55. Zagra L, Villa F, Cappelletti L, Gallazzi E, Materazzi G, De Vecchi E. Can leucocyte esterase replace frozen sections in the intraoperative diagnosis of prosthetic hip infection? Bone Joint J. 2019;101-B(4):372–7.
56. Nguyen M, Sukeik M, Zahar A, Nizam I, Haddad FS. One-stage exchange arthroplasty for periprosthetic hip and knee joint infections. Open Orthop J. 2016;10:646–53.
57. Zimmerli W. Prosthetic-joint infections. N Engl J Med. 2004;351:1645.
58. Svensson K, Rolfson O, Kärrholm J, Mohaddes M, et al. J Clin Med. 2019;8(4):485.
59. Vendittoli P-A, Massé V, Kiss M-O, Lusignan D, Lavigne M. Modular junction may be more problematic than bearing wear in metal-on-metal total hip arthroplasty. Hip Int J Clin Exp Res Hip Pathol Ther. 2019;29(3):262–9.
60. Koff MF, Esposito C, Shah P, Miranda M, Baral E, Fields K, et al. MRI of THA Correlates with implant wear and tissue reactions: a cross-sectional study. Clin Orthop. 2019;477(1):159–74.
61. Grammatopoulos G, Grammatopolous G, Pandit H, Kwon Y-M, Gundle R, McLardy-Smith P, et al. Hip resurfacings revised for inflammatory pseudotumour have a poor outcome. J Bone Joint Surg Br. 2009;91(8):1019–24.
62. Porter DA, Urban RM, Jacobs JJ, Gilbert JL, Rodriguez JA, Cooper HJ. Modern trunnions are more flexible: a mechanical analysis of THA taper designs. Clin Orthop. 2014;472(12):3963–70.
63. Meftah M, Haleem AM, Burn MB, Smith KM, Incavo SJ. Early corrosion-related failure of the rejuvenate

modular total hip replacement. J Bone Joint Surg Am. 2014;96(6):481–7.
64. Della Valle CJ, Calkins TE, Jacobs JJ. Diagnosing taper corrosion: when is it the taper and when is it something else? J Arthroplasty. 2018;33(9):2712–5.
65. Fink B. What can the surgeon do to reduce the risk of junction breakage in modular revision stems? Arthroplasty Today. 2018;4(3):306–9.
66. Jeffers JRT, Walter WL. Ceramic-on-ceramic bearings in hip arthroplasty: state of the art and the future. J Bone Joint Surg Br. 2012;94-B(6):735–45.
67. Im C, Lee K-J, Min B-W, Bae K-C, Lee S-W, Sohn H-J. Revision total hip arthroplasty after ceramic bearing fractures in patients under 60-years old: mid-term results. Hip Pelvis. 2018;30(3):156–61.

Revision Total Hip Arthroplasty: Surgical Technique

5

Ana Cruz-Pardos, Ricardo Fernández-Fernández, and Eduardo García-Rey

5.1 Introduction

Total hip arthroplasty (THA) remains one of the most successful surgical procedures and it has been considered the "Surgery of the Twentieth Century" [1]. Revision THA is a challenge for the orthopedic surgeon and has one main goal: the restoration of function and hip biomechanics. Despite the continuous improvements with regard to hip implant materials and design, alongside new approaches which limit soft tissue damage, primary hip arthroplasty failure continues to occur. In revision hip surgery, the first step is to correctly diagnose the underlying hip problem. Taking this into account, the surgeon must carefully evaluate the patients' symptoms and the consecutive radiological changes of the implant. In the previous chapter, the epidemiology and etiology of revision hip surgery have been explained. In this chapter we will present the surgical planning, including the preoperative evaluation of the painful total hip arthroplasty, the preoperative planning for revision hip arthroplasty, and the classification of bone defects. Once the surgeon has decided on the etiology of the failure of the THA, he should carry out an adequate surgical technique: the correct chosen approach (posterior, lateral, extended trochanteric osteotomy), how to best remove the components using specific techniques for cemented and uncemented prostheses, and, finally, how to reconstruct the hip. This latter concern will be addressed in later chapters.

5.2 Indications

The indications for revision total hip replacement have been discussed in Chap. 4.

5.3 Surgical Planning

Prior to performing a revision hip surgery, the orthopedic surgeon must follow a series of steps to determine the etiology of total hip arthroplasty failure.

5.3.1 Evaluation of the Symptomatic Total Hip Arthroplasty

The central aspect of any evaluation is a thorough history and physical examination. Patients may report pain, instability, weakness, sensory

A. Cruz-Pardos (✉) · R. Fernández-Fernández
E. García-Rey
Department of Orthopedic Surgery, Hip Unit, "La Paz" University Hospital, Madrid, Spain
e-mail: ana.cruz@salud.madrid.org

E. C. Rodríguez-Merchán (ed.), *Revision Total Joint Arthroplasty*,
https://doi.org/10.1007/978-3-030-24773-7_5

deficit, or even limb length discrepancy. Physical examination must include a full spine and hip evaluation, alongside a vascular and sensorial evaluation of the lower limb.

5.3.1.1 Pain

Pain is the most common complain following THA. A detailed questionnaire is mandatory to assess the cause of the pain.

- The location: pain may be referred to the groin, buttock, lateral thigh, or trochanteric area. In general, groin and buttock pain is associated with the acetabular component and an anterior thigh pain with the femoral component. There are some exceptions: patients with an iliopsoas tendinitis can have referred groin pain and, buttock pain may be caused by sacroiliac problems.
- Time of onset: it is important to know if the pain has appeared recently or if it has been present since the initial operation. A symptom-free period may suggest aseptic loosening or a late infection, and these must be considered.
- Pain severity and characteristics: Pain that increases with walking or standing but is relieved with rest is usually associated with aseptic loosening. However, pain that increases with rest or at night is more likely to be related to infection.

5.3.1.2 Instability

Patients that have suffered an episode of dislocation have a greater risk for recurrent dislocations. Some predisposing risk factors such as female gender, older patients, a high body mass index, previous hip surgery, a suboptimal position of the component (retroversion or vertical acetabular position), trochanteric nonunion, neurological impairment, or low-back stiffness must be considered when the surgeon evaluates these patients. Clinical subluxation is less frequent and is usually associated with polyethylene wear or muscular imbalance.

5.3.1.3 Limb Length Discrepancy

One of the goals of THA is to restore the correct hip biomechanics and limb length. Limb length discrepancy (LLD) is one of the main causes of litigation in many countries, so it is an important concern after surgery. Most patients will tolerate a shorter leg after surgery if the LLD is less than 1.5 cm. However, overlengthening is poorly tolerated. Fortunately, the majority of these LLD can be treated conservatively.

5.3.1.4 Other Symptoms

Other symptoms that must be considered are stiffness or a reduction in the range of movement and the vascular and sensory status of the limb. Spinal pathology or a peripheral vascular disease can present with pain around the hip or in the lower limb.

5.3.1.5 Physical Examination

Prior to a revision surgery, the physical examination of the hip does not differ from other situations. The surgeon must inspect the existing scars and assess the gait, limb length discrepancy, passive range of movement, lower limb, and abductor muscle weakness, and the vascular and neurological status of the limb including a motor and sensory assessment. A complete examination of the spine, as well as the contralateral hip and knee, must also be done. Considering all these data, one should define whether the cause of the hip pain is extrinsic (lumbar, trochanteric bursitis, abdominal, neurological or fracture) or intrinsic (loosening, sepsis, polyethylene wear, dislocation) [2].

5.3.2 Preoperative Planning for Revision Hip Arthroplasty

Preoperative planning for revision hip arthroplasty is critical, and all scenarios must be considered. It is a complex procedure with a higher risk of complications compared to primary THA, and we should pay attention to the existing implant, the bone quality, the previous approach and how to best remove the hardware. Therefore, the surgeon should have a variety of implants, grafts, and the use of intraoperative imaging techniques. After a complete clinical history and physical examination, other preoperative data must also be collected.

5.3.2.1 Laboratory Tests

In addition to conventional laboratory tests, the presence of periprosthetic joint infection (PJI) must be assessed. Serum C-reactive protein (CRP), D-dimer, and erythrocyte sedimentation rate (ESR) must be quantified, as well as synovial white blood cell count (WBC), polymorphonuclear percentage, leukocyte esterase, alpha-defensin, and synovial CRP. Intraoperative findings include frozen section, the presence of purulence, and isolation of a pathogen by culture [3]. According to the latest Consensus of the Musculoskeletal Infection Society (MSIS), two positive cultures or the presence of a sinus tract must be considered as major criteria and is diagnostic of PJI. The calculated weights of an elevated serum CRP (>1 mg/dL), D-dimer (>860 ng/mL), and erythrocyte sedimentation rate (>30 mm/h) were 2, 2, and 1 point, respectively. Furthermore, elevated synovial fluid WBC (>3000 cells/μL), alpha-defensin (signal-to-cutoff ratio >1), leukocyte esterase (++), polymorphonuclear percentage (>80%), and synovial CRP (>6.9 mg/L) received 3, 3, 3, 2, and 1 point, respectively. Patients with an aggregate score greater than or equal to 6 were considered infected, while a score between 2 and 5 required the inclusion of intraoperative findings for confirmation or refutation of the diagnosis. Intraoperative findings of positive histology, purulence, and a single positive culture were assigned 3, 3, and 2 points, respectively. Combined with the preoperative score, a total score greater than or equal to 6 was considered infected, a score between 4 and 5 was inconclusive, and a score of 3 or less was considered not infected. The new criteria demonstrated a higher sensitivity of 97.7% compared to the MSIS (79.3%) and International Consensus Meeting definition (86.9%), with a similar specificity of 99.5% [3] (Fig. 5.1).

5.3.2.2 Radiographic Evaluation

The radiographic evaluation includes an anteroposterior (AP) view of the pelvis and AP and lateral view of the affected hip, including the entire stem and the entire cemented area in cemented stems. Serial plain radiographs are the initial study of choice. These provide information related to the position and alignment of the prosthesis, changes in position, areas of osteolysis, stress shielding and remodeling changes, the quality of cement and interfaces, the quality of the greater trochanter, canal size, and other bone deformities. The surgeon must note the changes to the implant position and the bone, comparing it to previous films. Details that must be assessed are shown in Table 5.1 (Fig. 5.2).

Criteria for cemented implant loosening were described by Harris et al. [4]. Radiographic

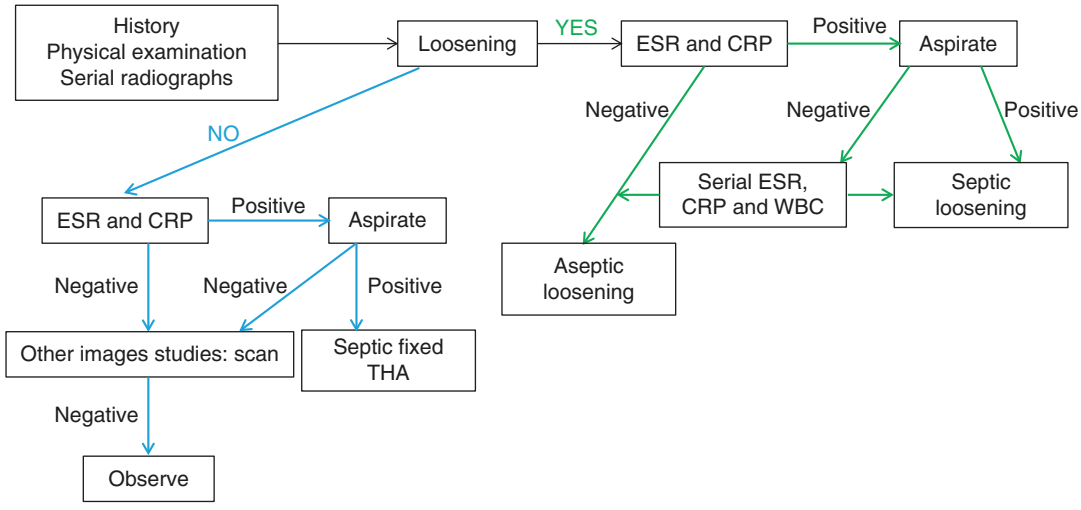

Fig. 5.1 Algorithm for the evaluation of a painful total hip arthroplasty (THA). *ESR* Erythrocyte sedimentation rate; *CRP* C-reactive protein; *WBC* White blood cell count

Table 5.1 Data to be evaluated on preoperative radiographs

Bone references on the acetabular side	
– Kohler line	– Medial and anterior wall
– Isquion area	– Posterior column and posterior wall
– Teardrop	– Medial wall and posterior column
– Superior migration of the cup	– Acetabulum roof
Interface	
– Bone-implant	
– Cement-bone	
– Cement-implant	
Osteolysis areas	
Radiolucent lines around the implants	
Quality of greater trochanter	
Position of the implants	
Wear polyethylene	
Pelvic discontinuity	

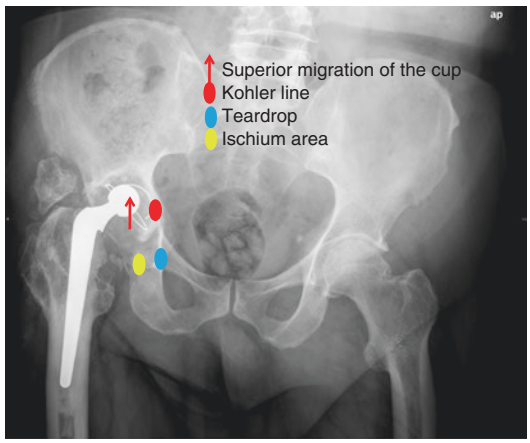

Fig. 5.2 Bone references on the acetabular side

Table 5.2 Radiographic signs of osseointegration and loosening

Definitive cemented femoral loosening
– Migration of the stem
– A continuous radiolucent line around the stem-cement interface
– A fracture of the stem
– A fracture in the cement mantle
Probable cemented femoral loosening
– A complete radiolucent line around the bone-cement interface
Possible cemented femoral loosening
– A radiolucent line extending between 50% and 100% of the bone-cement interface
Definitive uncemented femoral osseointegration: bone ingrowth
– No subsidence or stem migration
– No radiolucent line around the stem
– Presence of spot welds
Stable fibrous fixation of an uncemented stem
– No progressive subsidence
– A radiodense parallel, nonprogressive line around the stem less than 1 mm of diameter
– No other bone changes
Uncemented stem loosening
– Progressive subsidence or migration of the stem
– A radiolucent line around the stem greater than 1 mm of diameter
– A bone pedestal extending partial or completely across the intramedullary canal
– Hypertrophy cortical
Radiographic signs of osseointegration of porous coated uncemented cups
– Absence of radiolucent lines
– Presence of superolateral buttress
– Presence of medial stress shielding
– Presence of radial trabecular pattern
– Presence of inferomedial buttress
Cup loosening
– A progressive radiolucent line around the cup
– Changes in position or migration of the cup

assessment of cementless implant stability was described by Engh et al. [5] and Moore et al. [6]. All these criteria are shown in Table 5.2 [4–8].

5.3.2.3 Other Imaging Techniques

In addition to the radiographic study, in many cases it is necessary to perform other imaging techniques.

– Computed tomography (CT) scan: Frequently, radiographs underestimate the size and the location of osteolysis and bone defects, and a CT scan can be especially useful to assess the quality of acetabular bone. They can also be used to diagnose infection as they can reveal fluid collections or joint distensions and, in cases of recurrent dislocation, help to more accurately assess the position of the implants.
– Magnetic resonance imaging (MRI) can be used to assess the presence of pseudotumors and muscle damage in cases of metal-on-metal THA.
– Nuclear medicine images: Technetium-99m (Tc-99) bone scintigraphy is frequently used to assess the stability of cemented implants, but it is not very specific because many other

causes can increase the radionuclide uptake, such us infection, tumors, Paget's disease, etc. In general, a negative or normal result excludes a diagnosis of loosening and provides more information than an abnormal scan. Tc-99 bone scans appear to be of limited usefulness in the evaluation of loosening in cementless implants.

The use of scintigraphy with gallium-67 (Ga-67), indium-111, or marked leukocyte is more sensitive for the diagnosis of infection [9].

5.3.3 Classification of Bone Defects

Once the surgeon has decided to perform a revision surgery, the following step is to classify the bone defect. Bone defects around the femur and the acetabulum will determine the reconstruction technique. Several classifications have been described to classify the bone loss around the components.

5.3.3.1 Acetabular Bone Defects

The American Academy of Orthopedic Surgeons Committee on the Hip (D'Antonio Classification) distinguishes two types of defects: segmentary, when there is a loss of the bone affecting the supporting walls or columns of the acetabulum, and cavitary, when the defect involves a volumetric loss of bone with the rim and medial wall intact [10]. Other classifications have been proposed to describe the extent of periacetabular bone loss in revision THA [11], such as Paprosky et al. [12], Saleh et al. [13], Gustilo and Pasternak [14], Gross et al. [15], Parry et al. [16], and Engh et al. [17].

One of the most used classification systems is the one described by Paprosky et al. in 1994 [12]. This is based on anatomical references (medial wall-teardrop, hip center-superior dome, Kohler line-anterior column, and ischium lysis-posterior column) and on the presence or absence of an intact acetabular rim and its ability to provide rigid support for an implanted acetabular component (Fig. 5.3). Based on the structures which are deficient, and the degree of hip center migration, Paprosky et al. offered recommendations regarding the type and amount of supplemental allograft needed for reconstruction, methods of graft fixation, and implant selection.

Berry et al. defined pelvic discontinuity as a distinct form of bone loss, occurring in association with total hip arthroplasty, in which the superior aspect of the pelvis is separated from the inferior aspect because of bone loss or a fracture through the acetabulum [18]. It can be identified in preoperative radiographs as (1) a transverse fracture of the pelvis on the AP view, (2) a medial migration of the inferior hemipelvis related to the superior hemipelvis (a broken Kohler line), and a (3) rotation of the inferior hemipelvis in relation to the superior hemipelvis (asymmetry of the obturator foramen). Berry subclassified the AAOS type IV defects into three categories [18]: type IVa (pelvic discontinuity with cavitary or moderate segmental bone loss), type IVb (severe segmental loss or combined segmental and massive cavitary bone loss), and type IVc (previously irradiated bone with or without cavitary or segmental bone loss).

5.3.3.2 Femoral Bone Defects

To classify femoral bone defects, we can use the classification of the American Academy of Orthopedic Surgeons Committee on the Hip (D'Antonio Classification) [19] or Paprosky et al. [20], a classification system that defines femoral insufficiency based on the location of the bone loss and the degree of severity and proposes a treatment algorithm for surgical reconstruction based on these, which may allow surgeons to plan preoperatively for the type of femoral implant necessary to achieve a durable reconstruction (Fig. 5.4).

- Type I: defect in which minimal metaphyseal bone loss has occurred and the proximal femoral geometry is maintained. These defects are typically seen after removal of an uncemented implant with narrow metaphyseal geometry or following removal of an implant with minimal proximal ingrowth potential. These defects can be treated with a cylindri-

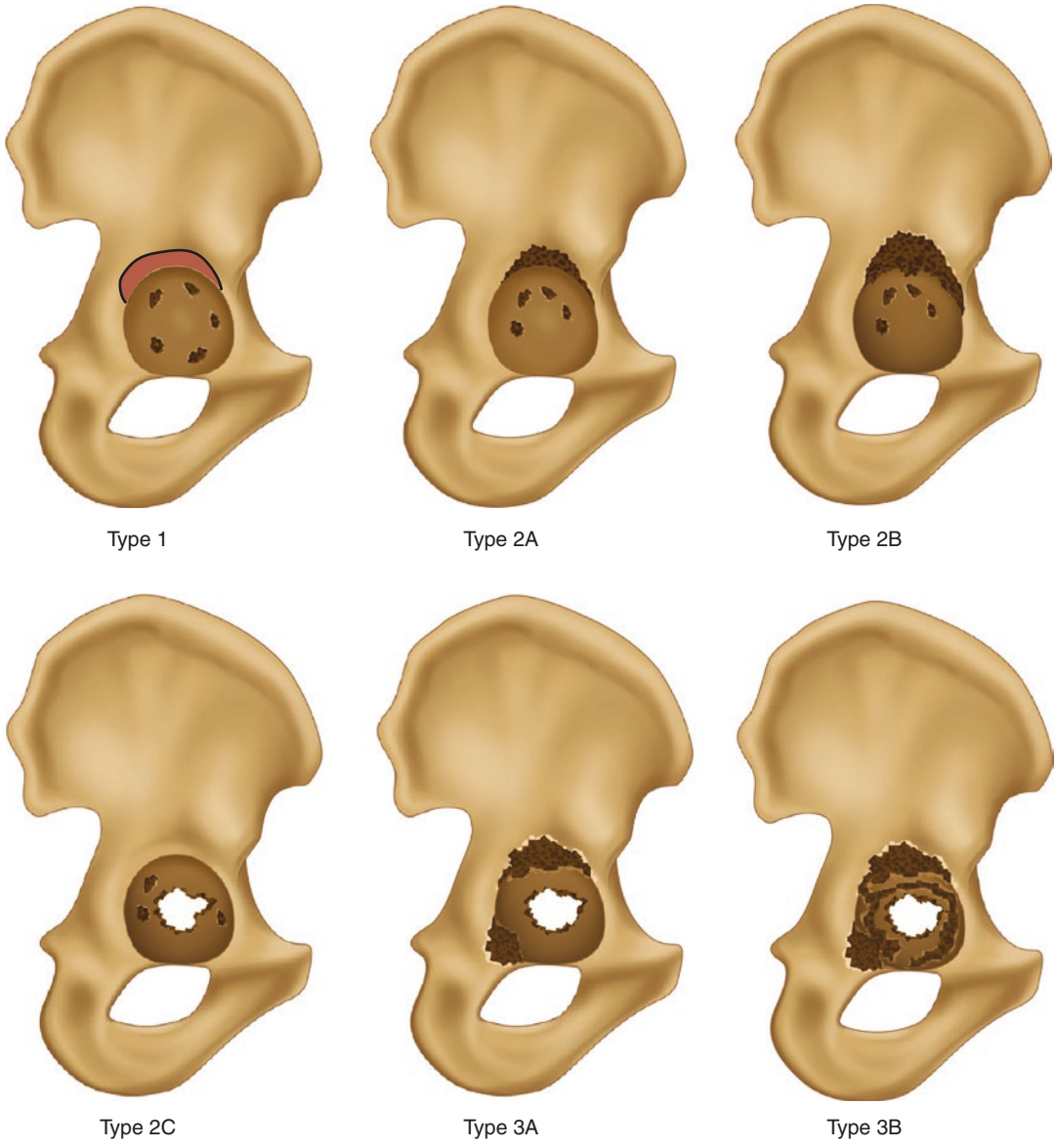

Fig. 5.3 Paprosky classification of acetabular bone defects

cal, extensively porous coated stem, or a tapered, proximally porous coated stem.

– Type II: a defect with extensive metaphyseal bone loss and minimal diaphyseal bone in which the proximal metaphyseal bone may not be mechanically supportive for a proximally fitting implant. The entirety of the diaphysis remains intact. These defects are commonly seen after removal of a cemented femoral implant or removal of a proximally fitting stem with a wide femoral geometry. In these cases, a femoral implant that engages the diaphysis, with an ongrowth surface or a porous ingrowth surface, is typically recommended.
– Type III defects are those in which the proximal metaphysis is completely unsupportive and the endosteal bone is severely deficient or absent. In Type IIIA there is more than 4 cm of intact diaphyseal bone available for distal

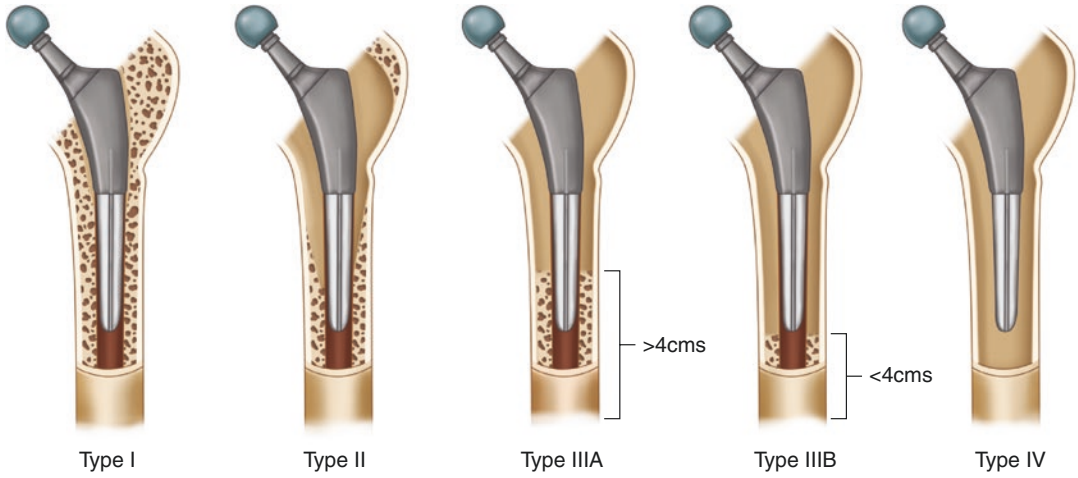

Fig. 5.4 Paprosky classification of femoral bone defects

fixation, and in Type IIIB there is less than 4 cm of diaphyseal bone available for distal fixation. The use of an extensively porous coated stem when at least 4 cm of intact diaphyseal bone was present is possible, but in Type IIIB defects, a tapered stem is preferred. Current total hip arthroplasties offer modularity, allowing for independent diaphyseal and metaphyseal fixation, with substantial intraoperative flexibility for version; limb length and offset can be also considered in these defects.

– Type IV are those with severe metaphyseal and diaphyseal bone loss, typically with severe ectasia (pronounced expansion of endosteal bone with profound cortical thinning) of the femoral canal, making uncemented fixation unreliable. Reconstruction options are usually limited to proximal femoral replacements, impaction grafting with a cemented stem, and allograft prosthetic composites.

For loose cemented stems, the four grades of Endo-Klinik classification are frequently used [21]:

– Grade I—radiolucent lines confined to the upper half of the cement mantle; clinical signs of loosening
– Grade 2—generalized radiolucent zones and endosteal erosion of the upper femur leading to widening of the medullary cavity
– Grade 3—widening of the medullary cavity by expansion of the upper femur
– Grade 4—gross destruction of the upper third of the femur with involvement of the middle third, precluding the insertion of even a long-stemmed prosthesis

5.4 Surgical Technique

5.4.1 Surgical Approaches in Revision Hip Surgery

Revision hip surgery requires the orthopedic surgeon to intimately know a wide a variety of surgical approaches, taking into account several basic principles such as the patient position on the operating table, providing an adequate exposure with minimal soft tissue damage, extended capsulotomy, and an adequate removal of the periosteum of the femur to allow an easy mobilization of the proximal femur away from the acetabulum. This must also be safe, simple, and anatomical. With these principles, the surgical approach in revision hip surgery can be the same as in primary THA [22]. Classification of surgical approaches is based on the approach to the hip capsule as anterior, lateral, or posterior. Most surgeons usually use a preferred approach to the hip for routine hip operations. This approach will be the one to which the surgeon was most widely

exposed during his training, but it is important that the surgeon be familiar with various approaches whenever necessary. We will now describe the most frequently used approaches in revision hip surgery.

5.4.1.1 Extended Posterior Approach

The posterior approach is probably the most commonly used approach for total hip replacement. The classic posterior approach, called Moore or Southern approach [23], is located over the posterior buttock and greater trochanter and continues down half of the femur. In revision surgery it is usually extended proximally and distally along the femoral diaphysis to better visualize the hip, acetabulum, and femur. Once the surgeon opens the fascia lata and has bluntly split the fibers of gluteus maximus, the external rotator muscles are exposed. The gluteus minimus is protected with a retractor and a flap, including the short external rotator tendons and capsule, and is made and reflected backward to protect the sciatic nerve and to visualize the prosthesis. This flap is then reattached toward the greater trochanter when the surgery has finished to maintain the tension of the abductor muscles (Fig. 5.5). The proximal femur is carefully skeletonized to allow an easy mobilization of it away from the acetabulum. With a maneuver of flexion, adduction, and internal rotation, the hip is dislocated, and two retractors are placed, one at the anterior capsule (at the 1 o'clock position for a right hip and at 11 o'clock position for a left hip) and the other inferiorly, next to the ischial tuberosity and the transverse acetabular ligament. In this way, the surgeon can expose the entire acetabulum and evaluate the stability of the cup. Only once the cup is removed and the bone is cleaned of fibrous tissue can the bone defect be evaluated, paying special attention to the anterior column, the posterior column, the roof, and the ischium. This approach can be extended proximally, if it is necessary, toward the iliac crest for exposure of the ilium and distally, down the line of the femur, as far as the level of the knee. Also, vastus lateralis may either be split or elevated from the lateral intermuscular septum.

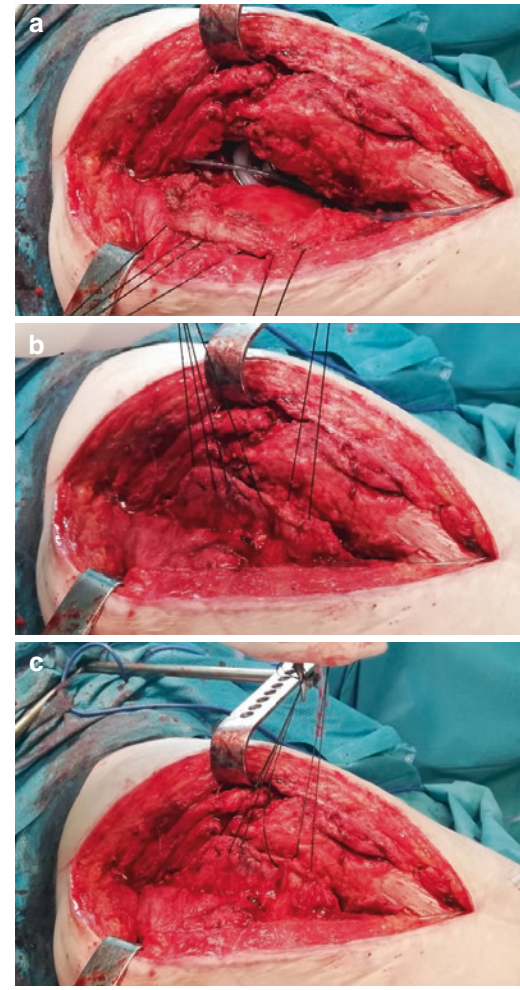

Fig. 5.5 Posterior approach: (**a**) A flap, including the short external rotator tendons and capsule, is reflected posteriorly to protect the sciatic nerve. (**b**) The flap is approximated once the surgery has finished. (**c**) The flap is then reattached toward the greater trochanter when the surgery has finished to maintain the tension of the abductor muscles

5.4.1.2 Anterolateral Approach

This is known as the Watson-Jones [24] approach, and the hip is visualized in the intramuscular plane between the tensor fascia lata

and gluteus medius. However, though it is a good approach for primary THA, there is a limited exposure of the acetabulum in revision surgery.

5.4.1.3 Lateral Approach (Hardinge) [25]

The incision is straight, centered over the greater trochanter. The fascia is opened, and the tensor is separated proximally and the gluteus maximus posteriorly, exposing the insertion of the vastus medialis and gluteus medius muscles. The incision extends proximally in line with the gluteus medius fibers at the junction of the middle and posterior third which is elevated with the periosteum and the origin of vastus lateralis in one piece and retracted anteriorly. Distally, the incision is extended forward by the anterolateral aspect of the femur, and in this way the joint capsule is already exposed. Unlike the posterior approach, in this approach there is a potential for injury to the superior gluteal nerve if the incision is extended too far proximally. Postoperative abductor weakness and limping are frequently found with this approach.

5.4.1.4 Extended Trochanteric Femoral Osteotomy [26]

In revision hip surgery, removing the stem can be a challenge. In these cases, an extended trochanteric osteotomy as described by Paprosky, a modification of the femoral osteotomy by Wagner, may be necessary. This osteotomy was described using a posterior approach, although it may be done with an anterolateral approach also. The indications for this approach are

- A well-bonded distal bone-cement interface
- A femoral deformity in varus/valgus or other deformities that interfere with a straight reaming of the femoral canal
- Evidence of bone ingrowth in cementless stems
- Stems that have migrated and are, therefore, at risk of damage to the greater trochanter if we want to remove it proximally

The surgeon must plan the level of the osteotomy, taking into account the cement plug or the prosthesis and allowing a maximal exposure of the femoral canal but leaving 6 cm for diaphyseal fixation. A prophylactic cerclage wire is placed 2 cm distally to protect the intact femur from a possible fracture. Osteotomy can be performed prior to dislocation of the hip, following dislocation but prior to the removal of the femoral component or following dislocation and removal of the component. Whenever possible, it is preferable following dislocation and removal of the stem. The distal zone and all the posterior extent of the osteotomy are marked just anterolateral to the linea aspera with multiple small perforations that are connected with an oscillating saw. The width of the osteotomy must be one lateral third of the circumference of the femur. Wide osteotomes are then passed posteriorly to anteriorly across the osteotomy to crack the anterior cortex. In this way and, taking great care, the osteotomy can be opened, and the fragment displaced anteriorly to remove the cement mantle of the implant. Care must be taken at this point not to cause a fracture of the greater trochanter. The muscles must remain attached to the anterior cut of the bone. The osteotomy also allows visualization of the distal cement plug and a direct access to the canal for placement of a long stem. Once the new stem has been implanted, the osteotomy is closed and held with multiple cables (Figs. 5.6 and 5.7).

5.4.2 Removal of the Components

As we have previously described, preoperative planning is mandatory for this step. The surgeon must identify the implants to be removed, the liner and the screws, and have all the necessary tools for carrying it out. Most loose implants are

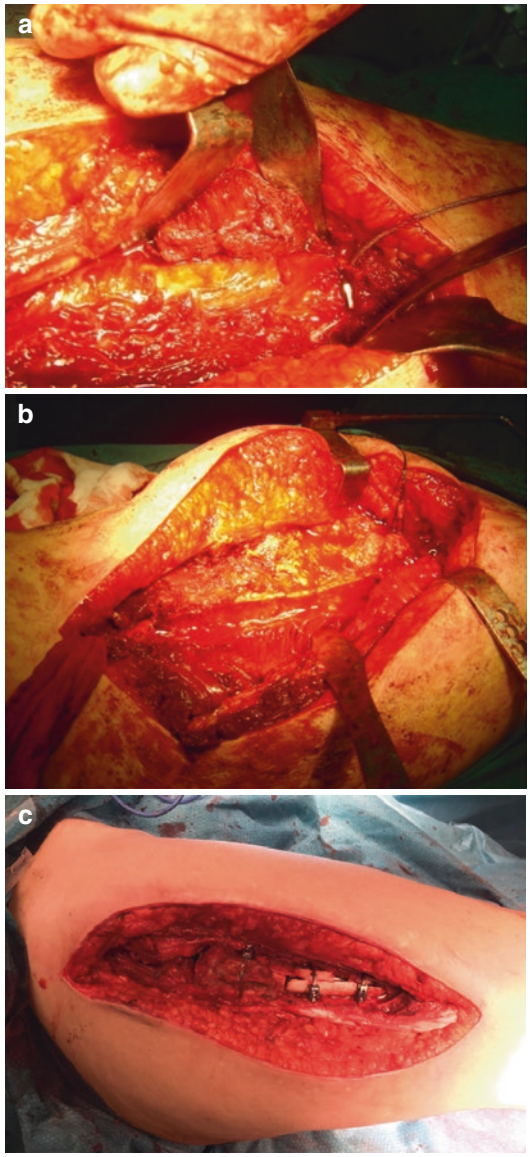

Fig. 5.6 Extended trochanteric femoral osteotomy: (**a**) A prophylactic cerclage wire is placed 2 cm distally to protect the intact femur from a possible fracture. (**b**) The femoral osteotomy is opened. (**c**) The osteotomy is closed and held with multiple cables

easily removed, and a variety of techniques have been described to remove well-fixed implants as well as cemented implants. These tools are available from most companies: high-speed instrumentations, ultrasonic tools, stem extractors, polyethylene liner extractors, cup extractors, screwdrivers, and modular head/neck detachment devices. In all cases, the surgeon should remove the implant while trying to preserve the largest bone surface.

5.4.2.1 Removal of a Cemented Cup

The removal of a cemented cup is easy using special curved osteotomes through the cement-prosthesis interface which gradually disrupt it, taking care not to lever against the bony rim. Once it is weakened, one can safely remove the cup with a gentle twist. Following this, one can remove the residual underlying cement mantle using once again straight, narrow, sharp osteotomes or curettage with a high-speed burr. In the event of intrapelvic cement, the surgeon can choose between leaving it or removing it with gentle traction and separating it from the fibrous layer around the cement without damaging the intrapelvic structures. Exceptionally, a retroperitoneal approach may be necessary to remove it. Other techniques described involve removing the cemented cup using a sharp acetabular reamer to ream out the polyethylene.

5.4.2.2 Removal of a Cemented Stem

The cemented stem is, in general, easily disrupted from the cement mantle when a retrograde force is applied, but, firstly, the cement above the lateral shoulder of the component and bone from the medial aspect of the greater trochanter must be removed to avoid a frac-

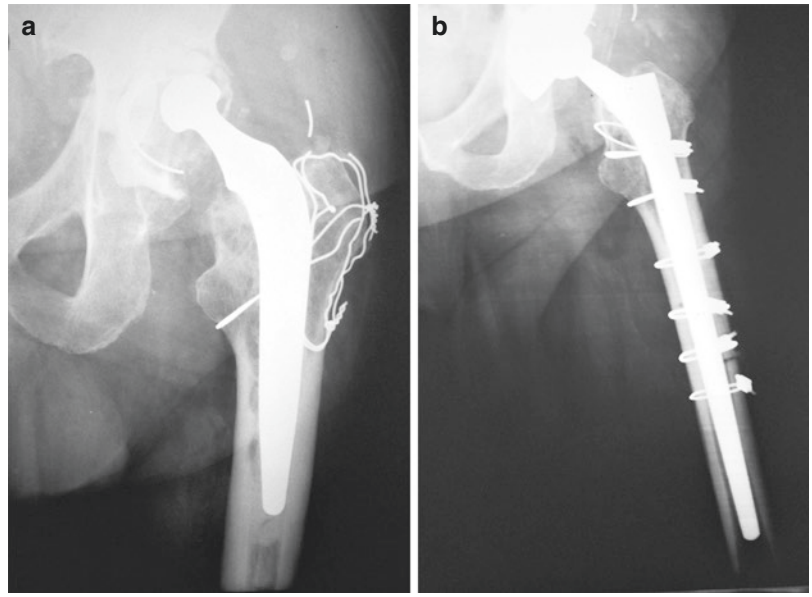

Fig. 5.7 (**a**) Preoperative loose cemented total hip arthroplasty. (**b**) Total hip arthroplasty after revision with an extended trochanteric femoral osteotomy

ture of the greater trochanter. If the component has a collar, the cement above also needs to be removed. Once the stem has been removed, the residual cement may be removed. The technique used for this depends on the surgeon's experience, and this can sometimes be easily performed with an extended trochanteric osteotomy. In the case of experienced surgeons, the cement can be carefully removed through the medullary femoral canal in three stages: metaphyseal cement above the lesser trochanter and diaphyseal cement below the lesser trochanter and then the distal cement plug. A high-speed burr, special straight osteotomes with T or V ending, or ultrasound is used to weaken and split the bone-cement interface at the metaphyseal and diaphyseal zones. In cases involving a well-fixed, thick cement layer connecting to the bone, any attempt to separate the cement with a gouge could cause a fracture. Therefore, longitudinal grooves should be made which allow the cement to be split safely. Removing the distal cement plug can be tedious. Under radioscopic control, a 4.5-mm or 6-mm drill is used to penetrate the distal cement plug, and then a thin hook curette can be used to slip in and disimpact it. Another alternative for removing the cement is to recement a stem into a preexisting cement mantle [27].

5.4.2.3 Removal of an Uncemented Cup

If the uncemented cup is fixed with supplementary screws, the polyethylene liner must first be removed. The polyethylene liner can be locked to the cup by different locking mechanisms, and specific tools to unlock them are required. There are two techniques described for removing the polyethylene liner. One uses a special threaded

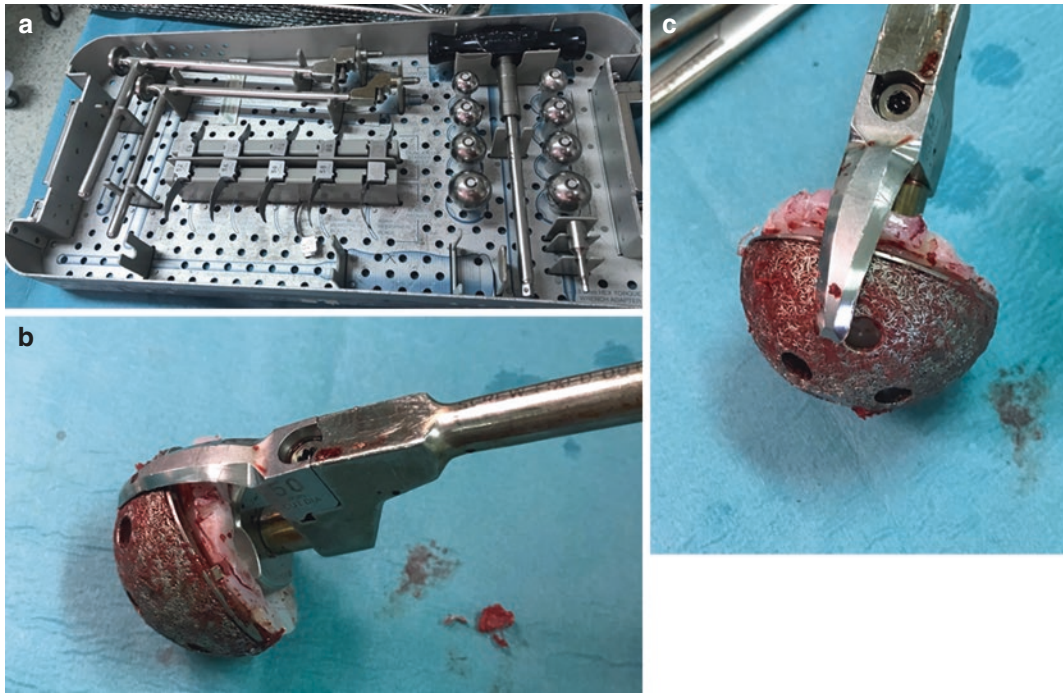

Fig. 5.8 Specific devices available to remove hemispherical acetabular components: (**a**) Shell removal instruments set with different blades and femoral heads; (**b**) handle with the femoral head and a long blade placed around the cup; (**c**) detail of the explanted cup with no bone around it

extractor device that drills a hole into the polyethylene; the extractor is then threaded, and, when it abuts the metal shell, the liner is forced out. Another alternative is to thread a 6.5-mm screw through the liner. If the cup has a ceramic liner, it can be forced out by hitting the metal back with small impactors. The screws in the shell are simply unscrewed with the appropriate screwdrivers.

Removing the cup can be done using curved and narrow osteotomes that are introduced between the cup and the bone and gradually progressing them around the cup. Nowadays, specific devices are available to remove hemispherical acetabular components (Fig. 5.8). These tools minimize the acetabular bone loss during revision surgery. They use the existing liner to centralize the femoral head, which matches the internal diameter of the acetabular cup. The head is threaded on the handle to stabilize and guide the curved blades during cutting. A short blade is slid in between the bone-cup interface and, with a rotating movement, progresses around the circumference of the cup. Following this, a long blade is used to repeat the process until the cup is loosened. Once the cup is completely loosened, it can be removed with a larger grasper. In the case of threaded cups or conical sockets, the shell is easily removed using fine, flexible osteotomes.

5.4.2.4 Removal of an Uncemented Stem

The extent of the removal of an uncemented stem depends on whether it is loose or well-fixed, as well as the type and extent of the porous coating. If the stem is loose, extraction requires a proximal fixation and a disimpaction

Fig. 5.9 Different types of osteotomes and tools used to remove cemented and uncemented stems: (**a**) straight and curved osteotomes; (**b**) instruments to remove the distal cement plug; (**c**) instruments to remove the stem

force. However, if the stem is well-fixed, special tools are required. The proximal part of the stem can be separated with thin, flexible osteotomes (Figs. 5.9 and 5.10). For the distal part, these osteotomes can be dangerous, and, if the surgeon encounters difficulties, an extended trochanteric osteotomy can be performed, and a Gigli saw or a high-speed burr may be used to remove the stem completely. Another alternative is to cut a cortical window in the femur and then cut the stem with a high-speed saw. The proximal part is, thus, removed, and the remaining distal part is loosened using trephines that disrupt the bone-prosthesis interface. Broken stems are usually well-fixed distally, and trephines are required to remove them.

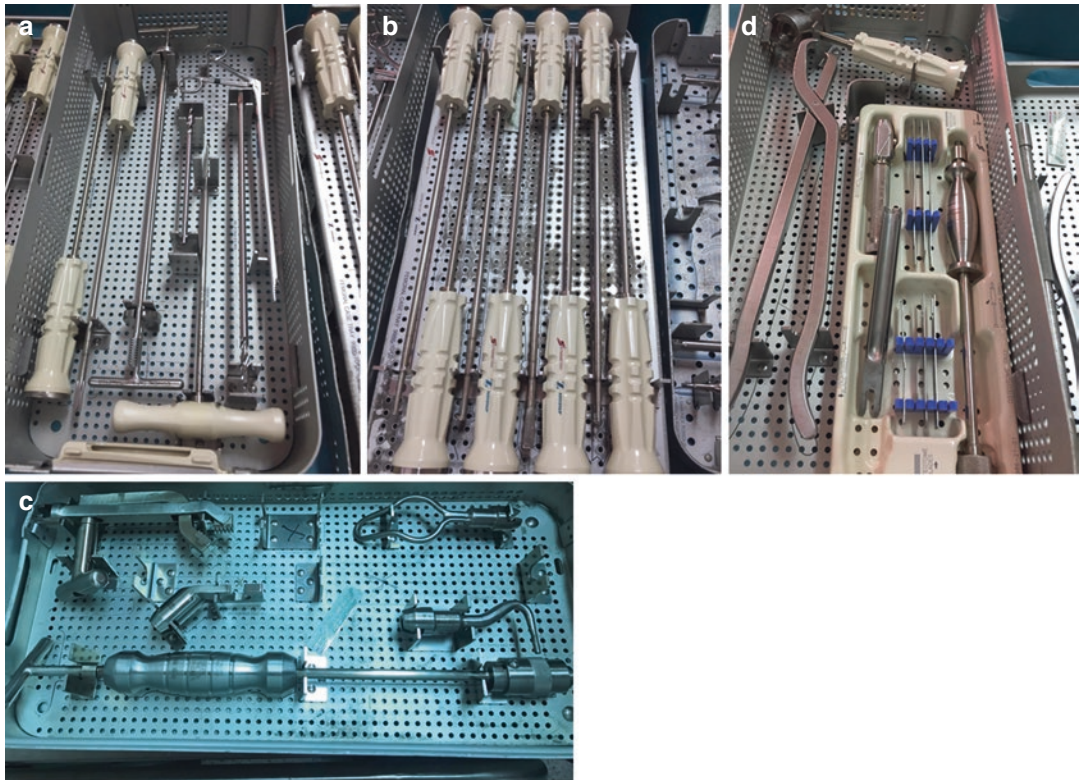

Fig. 5.10 Further types of osteotomes and tools used to remove cemented and uncemented stems: (**a**) instruments to remove the distal cement plug; (**b**) osteotomes and tools used for removing a cemented stem; (**c**) instruments to remove the stem; (**d**) flexible osteotomes to remove uncemented stems

5.5 Conclusions

Revision hip surgery presents a challenge to the orthopedic surgeon. A broad spectrum of pathological conditions must be considered. Evaluation of a symptomatic hip arthroplasty is a sequential process that begins with a detailed clinical history and examination of the patient. To confirm or discard a suspected diagnosis, a series of complementary tests must be carried out, such as laboratory tests and radiological evaluation. The radiographic evaluation always begins with a conventional radiograph, but, in many cases, a CT scan or scintigraphy may be necessary to confirm the diagnosis or to better define the bone defect. Once the diagnosis is made, surgery is carefully planned to minimize the risks and potential complications. Firstly, the surgeon must be familiar with the implant to be removed, the bone defect present, and the surgical technique they are going to carry out. Hip approaches must be extensive to allow a good exposure of the prosthesis. Although the surgeon should be familiar with different hip approaches, when it comes to revision hip surgery, the surgeon should use the approach that they are most comfortable with. Similarly, he or she must have an intimate knowledge of the tools required to remove the implants. The removal of implants should be done with caution, avoiding increasing bone loss.

References

1. Learmonth ID, Young C, Rorabeck C. The operation of the century: total hip replacement. Lancet. 2007;370:1508–19.
2. Evans BG, Cuckler JM. Evaluation of the painful total hip arthroplasty. Orthop Clin North Am. 1992;23:303–11.

3. Parvizi J, Tan TL, Goswami K, Higuera C, Della Valle C, Chen AF, et al. The 2018 definition of periprosthetic hip and knee infection: an evidence-based and validated criteria. J Arthroplasty. 2018;33:1309–14 e2.
4. Harris WH, MCcarthy JC Jr, O'Neill DA. Femoral component loosening using contemporary techniques of femoral cement fixation. J Bone Joint Surg Am. 1982;64:1063–7.
5. Engh CA, Glassman AH, Suthers KE. The case for porous-coated hip implants. The femoral side. Clin Orthop Relat Res. 1990;261:63–81.
6. Moore MS, McAuley JP, Young AM, Engh CA Sr. Radiographic signs of osseointegration in porous-coated acetabular components. Clin Orthop Relat Res. 2006;444:176–83.
7. Schmalzried TP, Kwong LM, Jasty M, Sedlacek RC, Haire TC, O'Connor DO, et al. The mechanism of loosening of cemented acetabular components in total hip arthroplasty. Analysis of specimens retrieved at autopsy. Clin Orthop Relat Res. 1992;274:60–78.
8. Engh CA, Bobyn JD, Glassman AH. Porous-coated hip replacement. The factors governing bone ingrowth, stress shielding, and clinical results. J Bone Joint Surg. 1987;69B:45–55.
9. Merkel KD, Brown ML, Dewanjee MK, Fitzgerald RH Jr. Comparison of indium-labeled-leukocyte imaging with sequential technetium-gallium scanning in the diagnosis of low-grade musculoskeletal sepsis. A prospective study. J Bone Joint Surg Am. 1985;67:465–76.
10. D'Antonio JA, Capello WN, Borden LS, Bargar WL, Bierbaum BF, Boettcher WG, et al. Classification and management of acetabular abnormalities in total hip arthroplasty. Clin Orthop Relat Res. 1989;243:126–37.
11. Telleria JJ, Gee AO. Classifications in brief: paprosky classification of acetabular bone loss. Clin Orthop Relat Res. 2013;471:3725–30.
12. Paprosky WG, Perona PG, Lawrence JM. Acetabular defect classification and surgical reconstruction in revision arthroplasty. A 6-year follow-up evaluation. J Arthroplasty. 1994;9:33–44.
13. Saleh KJ, Holtzman J, Gafni AL, Jaroszynski G, Wong P, Woodgate I, et al. Development, test reliability and validation of a classification for revision hip arthroplasty. J Orthop Res. 2001;19:50–6.
14. Gustilo RB, Pasternak HS. Revision total hip arthroplasty with titanium ingrowth prosthesis and bone grafting for failed cemented femoral component loosening. Clin Orthop Relat Res. 1988;235:111–9.
15. Gross AE, Allan DG, Catre M, Garbuz DS, Stockley I. Bone grafts in hip replacement surgery. The pelvic side. Orthop Clin North Am. 1993;24:679–95.
16. Parry MC, Whitehouse MR, Mehendale SA, Smith LK, Webb JC, Spencer RF, Blom AW. A comparison of the validity and reliability of established bone stock loss classification systems and the proposal of a novel classification system. Hip Int. 2010;20:50–5.
17. Engh CA, Culpepper WJ II, Kassapidis E. Revision of loose cementless femoral prostheses to larger porous coated components. Clin Orthop Relat Res. 1998;347:168–78.
18. Berry DJ, Lewallen DG, Hanssen AD, Cabanela ME. Pelvic discontinuity in revision total hip arthroplasty. J Bone Joint Surg Am. 1999;81:1692–702.
19. D'Antonio J, McCarthy JC, Bargar WL, Borden LS, Cappelo WN, Collis DK, et al. Classification of femoral abnormalities in total hip arthroplasty. Clin Orthop Relat Res. 1993;296:133–9.
20. Ibrahim DA, Fernando ND. Classifications in brief: the Paprosky classification of femoral bone loss. Clin Orthop Relat Res. 2017;475:917–21.
21. Engelbrecht E, Heinert K. Klassifikation und Behandlungsrichtlinien von Knochensubsanzverlusten bei Revisionsoperationen am Huftgelenk mittelfrsige Ergebnisse. In: Primare und Revisionsalloarthroplastik Hrsg-Endo-Klinik. Hamburg: Springer; 1987. p. 189–201.
22. Onyemaechi N, Anyanwu E, Obikili E, Ekezie J. Anatomical basis for surgical approaches to the hip. Ann Med Health Sci Res. 2014;4:487–94.
23. Moore AT. The self-locking metal hip prosthesis. J Bone Joint Surg Am. 1957;39A:811–27.
24. Watson Jones R. Fractures of the neck of the femur. Br J Surg. 1936;23:787.
25. Hardinge K. The direct lateral approach to the hip. J Bone Joint Surg. 1982;64B:17–9.
26. Younger TI, Bradford MS, Magnus RE, Paprosky WG. Extended proximal femoral osteotomy. A new technique for femoral revision arthroplasty. J Arthroplasty. 1995;10:329–38.
27. Lieberman JR, Moeckel BH, Evans BG, Salvati EA, Ranawat CS. Cement-within-cement revision hip arthroplasty. J Bone Joint Surg. 1993;75B:869–71.

6 Revision Total Hip Arthroplasty: Complications and Results

Eduardo García-Rey, Ana Cruz-Pardos, and Ricardo Fernández-Fernández

6.1 Introduction

Revision total hip arthroplasty (THA) procedures are increasing during the last decades in the whole world [1]. Despite reports from national registers indicating that recent innovations in technology and enhanced recovery programs are improving outcomes, revision THA rates are still increasing [2]. The consequences are quite significant in most developed countries in terms of health-related issues such as quality of life and socioeconomics [3]. To date, important resources are needed, usually from large teaching institutions in order to optimize results [4].

Indications for revision THA include complex procedures which may in many cases require all-component revision surgery to manage dislocation, mechanical loosening, or infection [5]. These indications have been shown to determine revision THA results; aseptic loosening is usually the most frequent reason for revision THA, and infection and instability had inferior results [6, 7].

6.2 National Registry Data

National registry data from different countries report that causes for revision THA can change over the years and depend on when that particular THA was implanted. The Swedish Hip Arthroplasty Register (SHAR) differentiates between reoperation, "Reoperation includes all kinds of surgical intervention that can be directly related to an inserted hip arthroplasty irrespective of whether the prosthesis or one of its parts has been exchanged, extracted or left untouched," and revision, "Revision means that a hip arthroplasty-operated patient undergoes a further operation in which a part of or the whole prosthesis is replaced or extracted" [8]. The author found that the proportion of reoperations has remained stable in relation to the total number of primary THA since 1992. Some demographic variables have changed over the years, such as more women, being older, and more patients with inflammatory arthritis. Compared to the primary THA population, the reoperation group included more women, older patients, more complex comorbidities (ASA class 3 or higher), and patients with secondary arthritis (Fig. 6.1). Indications can also show interesting changes in terms of indications for removal of the previous implant: infection was the most frequent cause, while fracture and dislocation have decreased

E. García-Rey (✉) · A. Cruz-Pardos
R. Fernández-Fernández
Department of Orthopedic Surgery,
"La Paz" University Hospital, Madrid, Spain

E. C. Rodríguez-Merchán (ed.), *Revision Total Joint Arthroplasty*,
https://doi.org/10.1007/978-3-030-24773-7_6

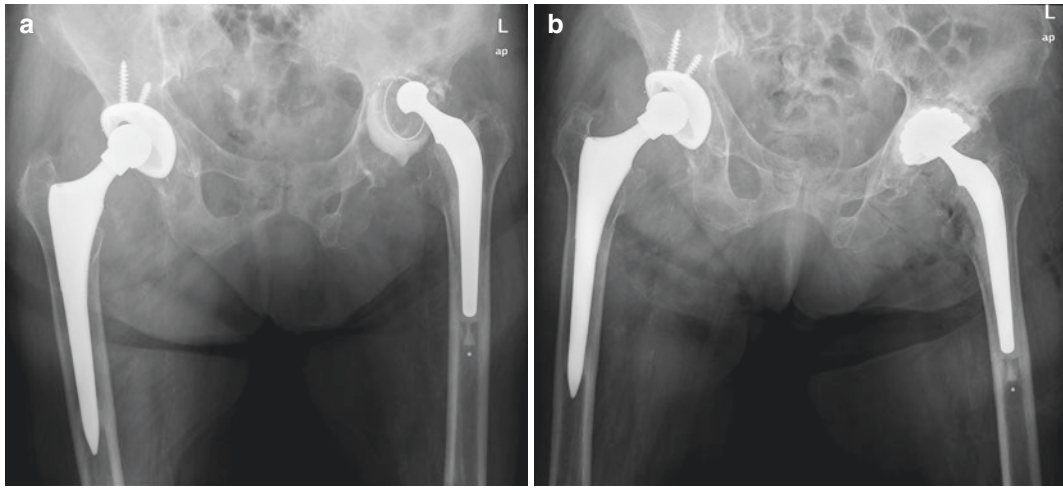

Fig. 6.1 (**a**) Radiograph of a total hip arthroplasty in a 93-year-old female patient showing cup loosening; (**b**) postoperative radiograph after revision hip surgery with a bone impaction grafting technique and a cemented dual-mobility cup

since revision procedures have been more frequently performed over the last years. Data on revision THA, the main analytic focus in most registers, show that it is increasing, as mentioned above.

The classic reasons for revision have been aseptic loosening and wear-related complications, but this must be interpreted depending on whether it is a first- or multiple-revision situation. To date, dislocations, infection, and fracture are increasing among multiple-revision patients and in older patients (Fig. 6.2). Finally, removal of the total implant or a component depends on the cause of revision: it is frequent to remove the entire implant in cases with infection, sometimes in cases with wear or loosening, the stem when there is a femoral fracture with associated osteosynthesis and the cup if there is a recurrent dislocation. Cemented or uncemented techniques require complex analysis since combined techniques with newer implants and the use of bone allograft are becoming more frequent.

Other national registries report complementary data. The National Joint Registry (NJR), from England and Wales, also shows that revision procedures are rising during the last years. It also reports aseptic loosening, lysis, and wear also as the most frequent reason for revision [9]. The Australian Register (AOANJRR) reports similar data for first-revision cases; however, it also shows that dislocation was the most frequent

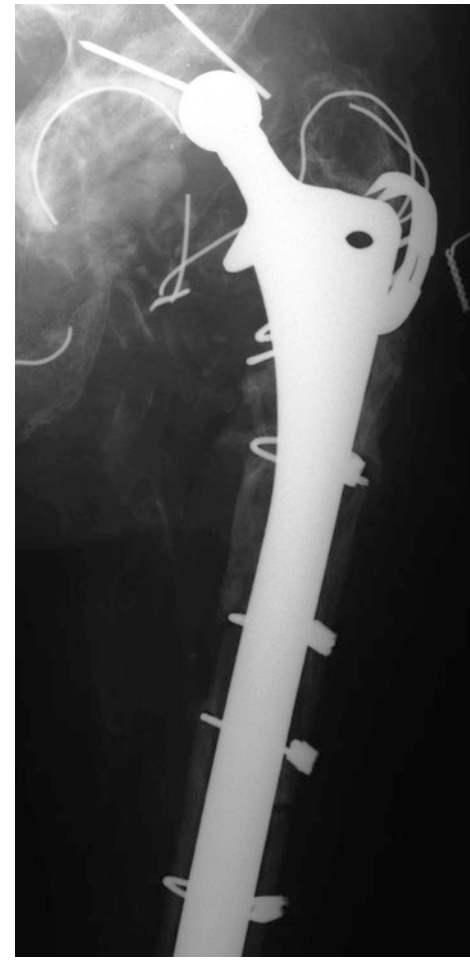

Fig. 6.2 Radiograph showing a dislocation after revision surgery with hip abductor deficiency

cause for revision during the first 4 years after primary THA after which time is aseptic loosening and lysis became the most frequent cause [10]. All registries also report the importance of introducing new implants, like large friction THA with hard-on-hard implants and their influence on results. Interestingly, the NJR and AOANJRR analyses include diagnoses such as adverse reactions and emphasize the importance of these problems.

6.3 Epidemiological Studies

In epidemiological studies it is important to comment that revision and primary THA rates oscillate across different geographic areas. Multiple causes have been investigated in order to explain these findings. The number of surgeons, providers, population access, and other socioeconomic reasons can influence these data. In Spain, regional variability was higher than expected [11]. Despite a universal health coverage system, equity may be challenged in the administration of hip arthroplasty. When hip replacement rates were adjusted for sex and age, the regional aging index, the density of orthopedic surgeons, and the regional health budget could only partially explain risk ratio changes. An interesting finding was the influence that the regional density of orthopedic surgeons had on the adjusted rates of primary and revision THA. Data have shown that patients in regions with more orthopedic surgeons are more prone to receive a primary THA; however, revision THA did not follow this tendency. Paradoxically, a significantly lower risk ratio for revision rates was found in regions with more orthopedic surgeons. This could be an expression of insufficient resources or qualification to perform revision hip surgery in regions with a higher density of general orthopedic surgeons, with subsequent unmet needs for the population. In fact, this finding could even reflect that the higher rate of revision hip procedures in areas with fewer surgeons could be associated with higher failure rates related to insufficient caseloads.

6.4 Complications and Outcome in Revision Total Hip Arthroplasty: Big Data

As previously described, the most frequent indication leading to a first-revision THA procedure in most is mechanical complications such as loosening and wear; however, in further reoperations, there are more complications related to more challenging surgeries such as infection, venous thromboembolic disease (VTE), or dislocation. First, it must be noted that these patients may be older and can have more comorbidities than those undergoing primary THA. A study of a US Medicare population observed that advanced age, rather than orthopedic complications, was a clear risk factor for VTE and mortality [12]. To date, comorbidities were also related to all complication types, but dislocation and infection rates are of particular importance. The NJR in England and Wales reported that dislocation and infection gained importance when compared to mechanical complications, wear, pain, or lysis reason for re-revision THA. In terms of 90-day mortality, this was also lower after primary THA than after revision. SHAR also confirmed these data in terms of more dislocation, infection, and complex patients in multiple-revision procedures. Thus, some complications such as periprosthetic fractures have higher dislocation rates, and this leads to changing indications meaning being prepared to change both the cup and stem rather than only the stem.

In terms of long-term survival after revision or re-revision surgeries, the last Annual Report from the SHAR confirmed that this was lower in both first- and multiple-revision THAs than for primary THA as expected. They have also observed that the risk of a revision was lower in female patients than in males. The 2017 NJR reports that the cumulative percentage probability of revision is increased three times overall at 13 years when comparing primary and revision THA rates. Similar to other registries, the reasons for re-revision due to infection and dislocation were higher in the latter. Last, mortality was lower after primary surgeries, and they did not find differences in between sexes. Registry data have also revealed complications in revision THA.

6.5 Dislocation After Revision Total Hip Arthroplasty

This complex and multifactorial problem is more challenging in revision than in primary THA. Previous surgery affects not only the long bone but also soft tissue around the hip. Abductor biomechanics are probably one of the most important factors [13]. Despite recent interest in implants with large femoral heads, modular stems, or dual-mobility cups leading orthopedic surgeons to introduce newer techniques, reconstruction of the center of the hip with a correct lever arm distance, height of the greater trochanter, and component position must be the main objective of the surgery to obtain good results. To date, preoperative planning to evaluate bone defects, including greater trochanter status, is critical. In a previous history of at least one dislocation, acetabular bone defect and abductor deficiency are the most important factors for dislocation [7] (Fig. 6.2).

After dislocation, careful assessment is mandatory. Re-revision rates are a big problem not only in number but in clinical morbidity and dissatisfaction. Re-dislocation and re-revision rates at 15 years can be higher than 30% and 40% when revision THA is done due to instability [14]. Repeated dislocation after two or more surgeries, small femoral heads, and liner exchange with cup retention has a higher risk. Some alternative options like constrained liner use have not improved re-revision rates. On the other hand, dual-mobility cups are gaining popularity given their better results when combined with proper assessment of the components, bone defect, and abductor deficiency issues [15].

6.6 Periprosthetic Fractures After Revision Total Hip Arthroplasty

This is a well-known as a challenging complication. During femoral revision surgery, the possible bone defect, as in the acetabulum, determines surgery [16]. Although femoral preoperative assessment can help in surgical planning, removal of the previous implant may change the strategy. Heterotopic calcifications, abductor deficiency with scar tissue and muscular atrophy, greater trochanter weakness, and cement or porous-coated implants are frequent local conditions that affect the final intraoperative bone defect. An intra- and postoperative periprosthetic femoral fracture can occur regardless of the choice of implant type [17]. In order to facilitate femoral component extraction, an extended femoral osteotomy has been reported [18]. This technique can be effectively performed and combined with different reconstruction techniques like impaction bone grafting [19] (Fig. 6.3).

The first problem after a periprosthetic fracture has occurred is to diagnose and classify [20]. During revision there are many factors that influence the appearance of a fracture, as mentioned above. Any audible crack or a changing resistance during impaction must be checked with imaging in order to detect. The

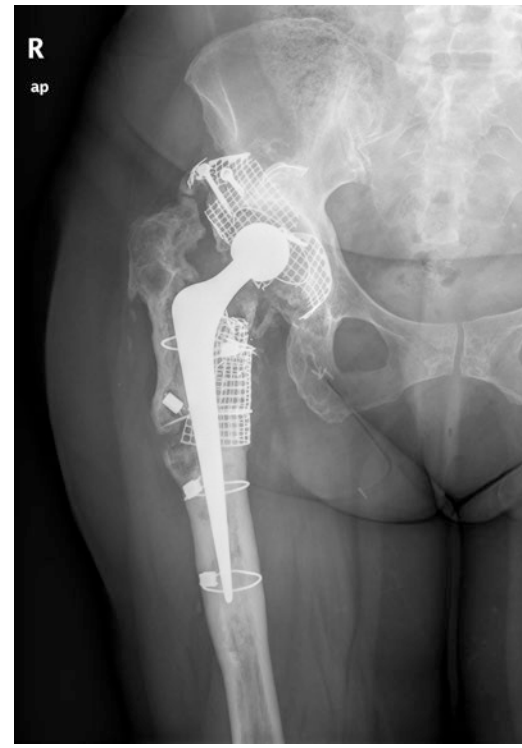

Fig. 6.3 Radiograph showing a femoral impaction bone grafting technique with a cemented stem combined with an extended trochanteric osteotomy

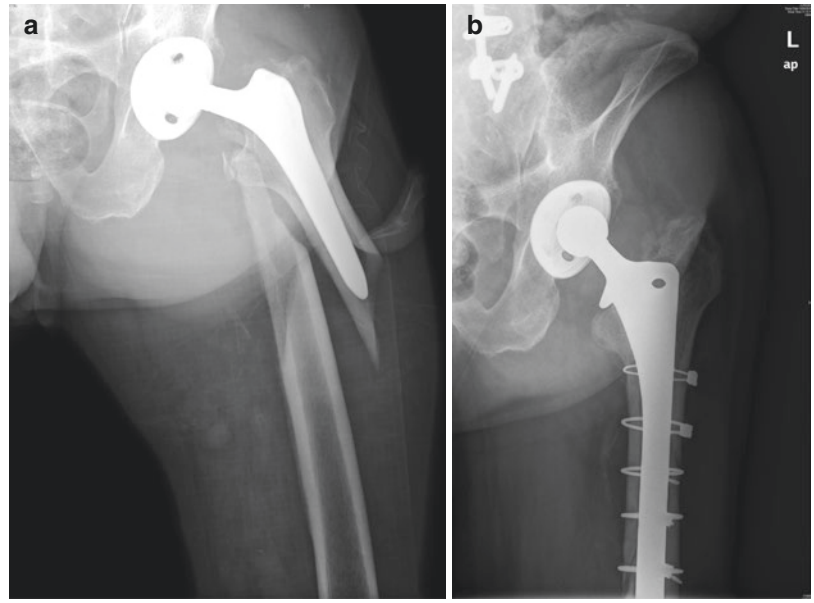

Fig. 6.4 (**a**) Radiograph showing a periprosthetic fracture in an 85-year-old patient. A loosened stem was found intraoperatively; (**b**) postoperative radiograph after revision hip surgery with a cementless long-stem and cerclage wires

explanation for intraoperative fracture management cerclage wires and a complete set with screws and plates must be ready for use. When a periprosthetic fracture is found after a given time after revision surgery, proper classification is critical [21] (Fig. 6.4). A distal femoral fracture is relatively easy to identify; however, the treating surgeon ought to suspect a loosened femoral component when a fracture occurs around the stem. Finally, refracture after a periprosthetic fracture is a very complex situation with a relatively high rate for infection, malunion, and residual limping and is usually related to a poor outcome [22] (Fig. 6.5).

6.7 Infection and Other Complications After Revision Total Hip Arthroplasty

This devastating complication is more challenging to manage than after a primary THA. Mortality rates are high after 1 and 5 years [23]. Despite its generally low incidence, this complication is more frequent after revision than after primary THA, and its incidence has risen during the last years meaning it has become a significant problem [24]. It is also well known that revision THA due to infection has more complications that aseptic revi-

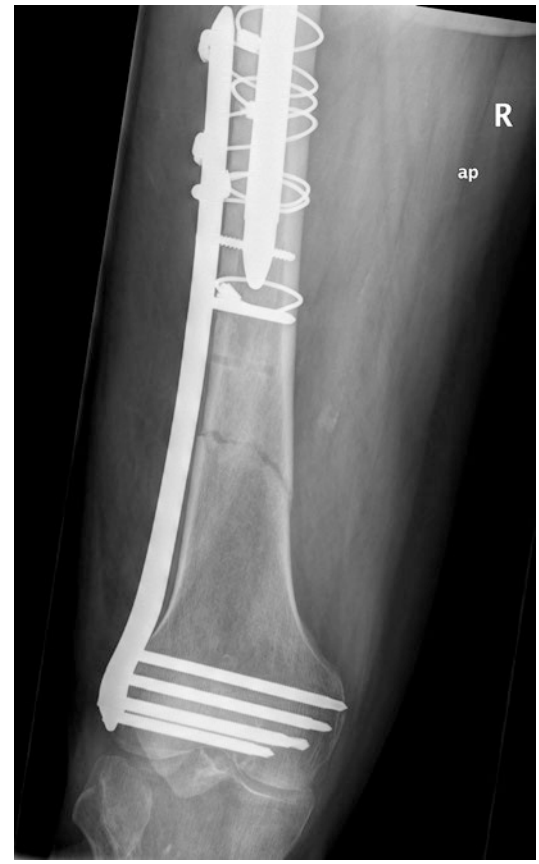

Fig. 6.5 Osteosynthesis of a periprosthetic femoral fracture distal to a previous cementless long stem implanted due to another previous fracture

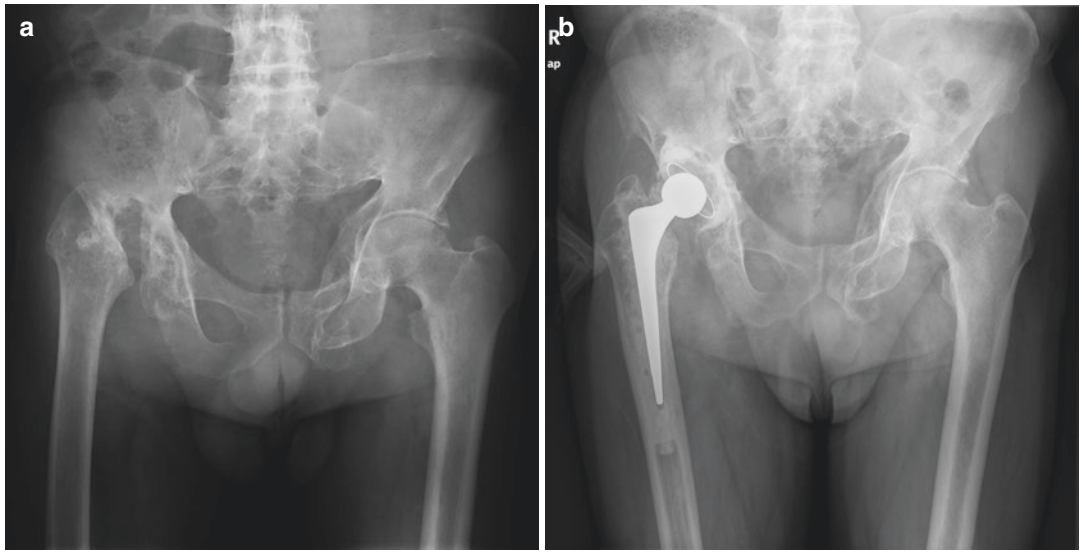

Fig. 6.6 (**a**) Sixteenth-year postoperative radiograph of an arthroplasty resection of the hip due to a periprosthetic total hip arthroplasty; (**b**) fifth-year postoperative radiograph after a bone impaction grafting technique on acetabular and femoral sides

sion THA like higher re-infection rates, non-home discharges and lengh of stay [25].

The approach taken must be similar to that for a periprosthetic joint infection after primary THA. However, the situation in these patients is a more complex situation; bone defects and soft tissue problems are frequent, and new and more intraoperative cultures are necessary to evaluate the infection [26]. Usually, a two-stage strategy is recommended due to the associated risk factors for reinfection [27]. For definite reconstruction of the hip, again the resulting bone defect is critical for determining surgical technique [28] (Fig. 6.6).

Not least, the possibility of a neurovascular complication must be kept in mind. Despite its low frequency, a major vascular injury can be devastating. Proper planning, particularly including acetabular bone imaging, is necessary to assess bone loss and the presence of metallic implants and medial defects [29]. The safe zone for extraction and the insertion of new, frequently more screws than before must be considered and planned for [30]. Lastly, extensive approaches around the iliac through the gluteus or dissection of scars and previous fibrous tissue around the proximal femur can also be possible origins of vascular trauma and bleeding. Similarly, neurological injuries can occur due to traction and other intraoperative maneuvers. Preserving the soft tissue envelope, which is frequently disrupted due to different surgeries before the primary THA, is equally important, particularly in patients with childhood sequelae. In the same way, changes in greater trochanter status and that of muscle around this area, including the superior gluteal nerve, may add instability to the hip joint and are very difficult to treat.

Complications after revision THA are indeed challenging. Adequate knowledge of the problem is critical before treating these patients given the higher complication rate than in primary THA. Despite the relatively low frequency, the consequences increase mortality and morbidity rates sincere revision procedures have inferior results than the first revision.

6.8 Conclusions

Complications after revision THA are indeed challenging. Adequate knowledge of the problem is critical before treating these patients given the

higher complication rate than in primary THA. Improvements in register data during the last decades are providing interesting results after deep analysis with important clinical interpretations. Revision THAs are more and more complex procedures due to patient's age, comorbidities, and previous implants. Despite the relatively low frequency, the consequences increase mortality and morbidity rates since re-revision procedures have inferior results than the first revision.

Complications after revision THA are the same than after primary THA; however, there are some differences to note. Dislocation is gaining importance as the most frequent reason for revision after primary THA due to improvements in bearing surfaces performances during the last 20 years in contrast to wear, lysis, and loosening. Instability is more important after revision THA indeed. A proper reconstruction of the rotation hip center and the abductor mechanism is more difficult in major revision procedures. To date, deficiencies in proximal femur and gluteus muscles are relatively frequent particularly in patients with multiple-revision procedures. Surgical technique and alternative acetabular components such as dual-mobility cups may improve outcome.

Other major complication is a periprosthetic femoral fracture. Bone defect determines outcome in both acetabular and femoral sides. A detailed preoperative planning is critical before performing surgery, and all surgical issues ought to be ready. At this point, the surgeon must note that the final intraoperative bone defect will be determined after removal of the previous femoral component. Periprosthetic femoral fractures are more frequent after revision THA than after primary THA. Intraoperative, at an early or a late follow-up, is related to bone defect regardless during insertion of a new stem, an underdiagnosed fracture, of osteopenic bone.

Finally, infection is the most devastating complication. The surgeon ought to know the importance of not only early- but late-onset periprosthetic THA infection. As previously mentioned, the increasing patients' age and comorbidities are of influence at this point. Recent advances in modern oral antibiotic protocols and bone defect and soft tissue management are showing promising results.

References

1. Kurtz S, Ong K, Lau E, et al. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg. 2007;89:780.
2. Patel A, Pavlou G, Mújica-Mota RE, Toms AD. The epidemiology of revision total knee and hip arthroplasty in England and Wales: a comparative analysis with projections for the United States. A study using the National Joint Registry dataset. Bone Joint J. 2015;97-B:1076–81.
3. Lavernia CJ, Drakeford MK, Tsao AK, Gittelsohn A, Krackow KA, Hungerford DS. Revision and primary hip and knee arthroplasty. A cost analysis. Clin Orthop Relat Res. 1995;311:136–41.
4. Crowe JF, Sculco TP, Kahn B. Revision total hip arthroplasty: hospital cost and reimbursement analysis. Clin Orthop Relat Res. 2003;413:175–82.
5. Bozic KJ, Kurtz SM, Lau E, et al. The epidemiology of revision total hip arthroplasty in the United States. J Bone Joint Surg. 2009;91:128.
6. Jafari SM, Coyle C, Mortazavi SM, Sharkey PF, Parvizi J. Revision hip arthroplasty: infection is the most common cause of failure. Clin Orthop Relat Res. 2010;468:2046–51.
7. Wetters NG, Murray TG, Moric M, Sporer SM, Paprosky WG, Della Valle CJ. Risk factors for dislocation after revision total hip arthroplasty. Clin Orthop Relat Res. 2013;471:410–6.
8. Swedish Hip Arthroplasty Register. Annual report. Gothenburg: Svenska Höftprotesregistret; 2014. http://www.shpr.se/sv/Publications.aspx.
9. NJR. 15th Annual report. Hemel Hempstead: NJR; 2018. http://www.njrreports.org.uk.
10. Australian Orthopaedic Association National Joint Replacement Registry. Annual reports. Adelaide, SA: AOANJRR; 2016. http://aoanjrr.sahmri.com.
11. Padilla-Eguiluz NG, García-Rey E, Cordero-Ampuero J, Gómez-Barrena E. Regional variability in the rates of total hip replacement in Spain. Hip Int. 2014;24:81–90.
12. Badarudeen S, Shu AC, Ong KL, Baykal D, Lau E, Malkani AL. Complications after revision total hip arthroplasty in the Medicare population. J Arthroplasty. 2017;32:1954–8.
13. García-Rey E, García-Cimbrelo E. Abductor biomechanics clinically impact the total hip arthroplasty dislocation rate: a prospective long-term study. J Arthroplasty. 2016;31:484–90.
14. Jo S, Jimenez Almonte JH, Sierra RJ. The Cumulative risk of re-dislocation after revision THA performed for instability increases close to 35% at 15 years. J Arthroplasty. 2015;30:1177–82.

15. Hamadouche M, Biau DJ, Huten D, Musset T, Gaucher F. The use of a cemented dual mobility socket to treat recurrent dislocation. Clin Orthop Relat Res. 2010;468:3248–54.
16. Garcia-Cimbrelo E, Garcia-Rey E, Cruz-Pardos A. The extent of the bone defect affects the outcome of femoral reconstruction in revision surgery with impacted bone grafting: a five- to 17-year follow-up study. J Bone Joint Surg Br. 2011;93:1457–6.
17. Abdel MP, Houdek MT, Watts CD, Lewallen DG, Berry DJ. Epidemiology of periprosthetic femoral fractures in 5417 revision total hip arthroplasties: a 40-year experience. Bone Joint J. 2016;98-B:468–74.
18. Paprosky WG, Sporer SM. Controlled femoral fracture: easy in. J Arthroplasty. 2003;18(3 Suppl 1):91–3.
19. García-Rey E, Cruz-Pardos A, Madero R. The evolution of the technique of impaction bone grafting in femoral revision surgery has improved clinical outcome. A prospective mid-term study. J Arthroplasty. 2015;30:95–100.
20. Tsiridis E, Krikler S, Giannoudis PV. Periprosthetic femoral fractures: current aspects of management. Injury. 2007;38:649–50.
21. Lindahl H, Malchau H, Odén A, Garellick G. Risk factors for failure after treatment of a periprosthetic fracture of the femur. J Bone Joint Surg Br. 2006;88:26–30.
22. Randelli F, Pace F, Priano D, Giai Via A, Randelli P. Re-fractures after periprosthetic femoral fracture: a difficult to treat growing evidence. Injury. 2018;49(Suppl 3):S43–7.
23. Natsuhara KM, Shelton TJ, Meehan JP, Lum ZC. Mortality during total hip periprosthetic joint infection. J Arthroplasty. 2019;34:S337. pii: S0883-5403(18)31225-7.
24. Lenguerrand E, Whitehouse MR, Beswick AD, Jones SA, Porter ML, Blom AW. Revision for prosthetic joint infection following hip arthroplasty: evidence from the National Joint Registry. Bone Joint Res. 2017;6:391–8.
25. Boddapati V, Fu MC, Tetreault MW, Blevins JL, Richardson SS, Su EP. Short-term complications after revision hip arthroplasty for prosthetic joint infection are increased relative to noninfectious revisions. J Arthroplasty. 2018;33:2997–3002.
26. Cordero-Ampuero J. Girdlestone procedure: when and why. Hip Int. 2012;22(Suppl 8):S36–9.
27. El-Husseiny M, Haddad FS. The role of highly selective implant retention in the infected hip arthroplasty. Clin Orthop Relat Res. 2016;474:2157–63.
28. Garcia-Rey E, Cruz-Pardos A, Madero R. Clinical outcome following conversion of Girdlestone's resection arthroplasty to total hip replacement: a retrospective matched case-control study. Bone Joint J. 2014;96-B:1478–84.
29. Garcia-Cimbrelo E, Tapia M, Martin-Hervas C. Multislice computed tomography for evaluating acetabular defects in revision THA. Clin Orthop Relat Res. 2007;463:138–43.
30. Wasielewski RC, Cooperstein LA, Kruger MP, Rubash HE. Acetabular anatomy and the transacetabular fixation of screws in total hip arthroplasty. J Bone Joint Surg Am. 1990;72:501–8.

7 Revision Total Shoulder Arthroplasty: Epidemiology and Causes

Eloy Tabeayo, Konrad I. Gruson, and James M. Saucedo

7.1 Introduction

The history of shoulder arthroplasty begins in the late nineteenth century with Themistocles Gluck and Jules Emile Péan [1], but its clinical contribution to shoulder surgery remained relatively anecdotal until the initial design created in 1952 by Dr. Charles Neer, which served as a solution for complex proximal humerus fractures in which avascular necrosis and ankylosis were common complications [2]. At that time, the design was a monobloc humeral stem with only three sizes, and there was no option to resurface the glenoid. In 1974, he published his results with total shoulder arthroplasty for primary osteoarthritis, with an early design of a cemented polyethylene glenoid component [3]. Since then, shoulder arthroplasty design has continued to evolve into a wide variety of anatomic and reverse systems, including stemmed, stemless, cemented, cementless, and modular implants.

E. Tabeayo · K. I. Gruson
Department of Orthopedic Surgery, Montefiore Hospital, The Bronx, NY, USA
e-mail: kgruson@montefiore.org

J. M. Saucedo (✉)
Houston Methodist Orthopedics and Sports Medicine in Houston, Houston, TX, USA
e-mail: jsaucedo@houstonmethodist.org

7.2 Epidemiology

The incidence of shoulder replacement surgery is increasing worldwide. A 141.4% increase has been reported between 2008 and 2017 in Australia, with an annual incidence of 26/100,000 inhabitants in 2017 [4]. A similar trend has been reported in other countries, such as Norway, Sweden, New Zealand, Denmark, and Germany, with annual incidence rates anywhere from 8 to 34/100,000 [5].

Along with that dramatic increase, there has been a concomitant rise in the number of revision surgeries. With a reported revision rate of 2.8–10.9% [4, 6, 7], an increasing number of revision procedures can be expected as surgical indications are expanded.

The most common indications for total shoulder replacement include inflammatory arthritis, primary osteoarthritis, instability arthritis, postcapsulorrhaphy arthropathy, rotator cuff-deficient arthritis, advanced avascular necrosis, and intra-articular fractures. The underlying etiology seems to influence the clinical outcome and longevity of the implant.

In that regard, national registries have proven to be excellent tools to further analyze revision surgery. The Australia National Joint Registry of 2018, for example, is rich with information. In Australia, the revision rate for hemi-resurfacing arthroplasty is 12%, and the main reasons for revision are glenoid erosion and pain, which

E. C. Rodríguez-Merchán (ed.), *Revision Total Joint Arthroplasty*,
https://doi.org/10.1007/978-3-030-24773-7_7

account for almost 50% of revision cases. This is followed by rotator cuff insufficiency and component loosening. Of the total revisions, 54% follow a reverse shoulder arthroplasty, and 45% follow an anatomic arthroplasty. Patients aged 65–74 have a 50% reduced hazard ratio for revision compared to patients <55 years. There appears to be no difference in revision rates when comparing the underlying diagnoses in stemmed hemiarthroplasty (8.4% for fracture vs. 9.3% for osteoarthritis).

The indication for revision, however, does seem to vary according to the underlying diagnosis. In those cases where hemiarthroplasty was performed for a fracture, the most common reasons for revision were rotator cuff insufficiency, followed by instability, or dislocation. For those whose primary diagnosis was osteoarthritis, glenoid erosion was the most frequent reason for revision, followed by instability. Cemented stems and patients older than 75 years had a lower revision rate in the fracture group.

Anatomic total shoulder arthroplasty in the Australian National Joint Registry has demonstrated a rapid decrease since 2010 with a simultaneous increase in reverse shoulder arthroplasty, which accounted for over 70% of all the total shoulder arthroplasties performed during 2017. The revision rate for anatomic versus reverse shoulder arthroplasty was 12.6% and 7% at 10 years, respectively. Anatomic shoulder arthroplasty did not show different revision rates when performed for fracture, osteonecrosis, or osteoarthritis.

Rotator cuff insufficiency, instability, and loosening account for almost two-thirds of the reasons for revision in anatomic arthroplasties. Half of the revisions were of the humeral component only, and 20% of them involved revision of both the humeral and glenoid components. There was an increased rate of revision with cementless glenoid components and in patients younger than 55 years.

In the case of reverse shoulder arthroplasty, there was an increased rate of revision at 3 months when performed for fracture, but the rate stabilized after that. Instability, infection, loosening, and fracture accounted for over 85% of the revision causes. Age was not a reason for revision when performed for osteoarthritis, but when performed for fracture or rotator cuff arthropathy, patients older than 75 years had a lower revision rate [4].

7.3 Causes for Revision

7.3.1 Infection

Periprosthetic joint infection after total shoulder arthroplasty has been reported to have an incidence between 1% and 4% and accounts for 3–5% of all complications following anatomic total shoulder arthroplasty [8–11]. A higher infection rate has been reported following reverse shoulder arthroplasty, and it has been found to be up to 6.11 times greater than after anatomic shoulder arthroplasty [12]. It has been hypothesized that postsurgical hematoma formation in the subacromial space may contribute to its development [13, 14].

A systematic review by Zumstein et al. reported a 2.9% rate of deep infection rate after primary RTSA and 5.8% after revision RTSA [15]. Walch et al. compared their results after RTSA between the years 1995 to 2003 versus 2003 to 2007 and found a marked decrease in infection rates between those time periods (from 4% to 0.9%). The authors postulated that surgeon experience, perhaps through more refined indications and surgical technique, may be paramount to avoiding or minimizing this complication [16].

Some patient populations are at greater risk for deep infection, such as patients with rheumatoid arthritis. These patients reportedly have up to 2.6 times higher risk of infection after joint arthroplasty [17, 18]. A case-control study by Bala and colleagues found an increased risk of infection in patients with HIV infection (OR 1.36; 95% CI, 1.01–1.82) [19].

Smoking has also been correlated with increased infection rates with a hazard ratio of 7.27 for current smokers and 4.56 for former smokers (those who had not smoked within 1 month prior to surgery) [20]. In addition, an increased risk of infection after total shoulder

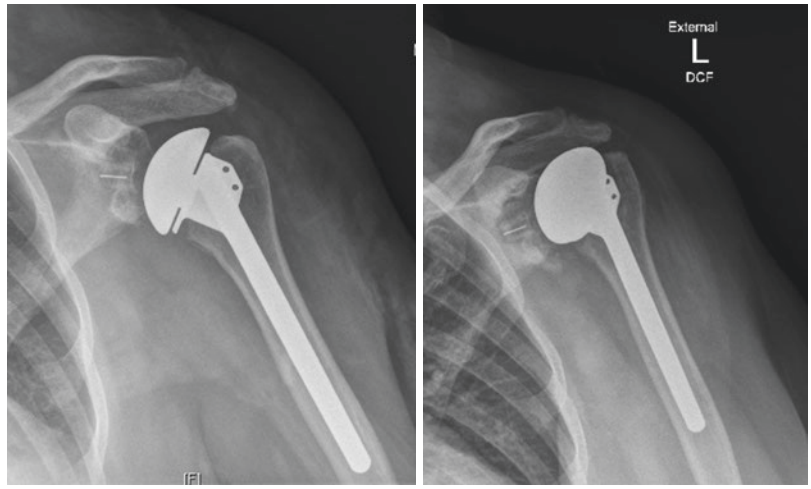

Fig. 7.1 In these images, the picture on the right shows an early glenoid component loosening, 1 year after the index procedure (picture on the left). A guided aspiration was obtained, and cultures were positive for *C. acnes* infection

arthroplasty has been found in male patients, those with a traumatic indication, prior local infection, prior non-arthroplasty shoulder surgery, revision arthroplasty, long-term corticosteroid use, and the need for perioperative allogeneic red blood cell transfusion [21, 22].

The most commonly cultured organisms in an infected shoulder arthroplasty are the *Cutibacterium acnes* (formerly Propionibacterium acnes) and coagulase-negative *Staphylococcus* spp. It is common to find these organisms in the setting of a subacute infection, where pain may be the only apparent manifestation and the classic signs of infection, such as fever, erythema, warmth, and purulence may be less prominent. A careful history can reveal details that help with the diagnosis, such as pain at rest and stiffness.

C. acnes is a well-known gram-positive rod found in the skin as a commensal, with younger male patients having a higher bacterial burden. It has been implicated in chronic skin diseases, such as acne vulgaris, and deep infections associated with prosthetic devices. Torrens et al. isolated positive cultures for *C. acnes* in the deep layers of 18.8% of their patients undergoing a primary reverse total shoulder arthroplasty. Of those cases, however, with a minimum follow-up of 1 year, only one patient (1.1%) developed an infection at 6 months after the procedure, suggesting that the presence of this organism does not guarantee an infection and may not be the only risk factor [23]. *C. acnes* infection is more frequently associated with male patients, cloudy synovial fluid, humeral osteolysis, humeral loosening, glenoid wear, and membrane formation (Fig. 7.1) [24].

More "classic" clinical findings suggesting infection may be encountered in the setting of a more aggressive organism, such as *Staphylococcus* or *Streptococcus* spp. In these instances, bone osteolysis and implant loosening, swelling, erythema, and increased blood infection markers may be present [12, 21, 25].

Diagnosis of infection can often be difficult, with pain and limited range of motion being the most common clinical complaints [26]. Good-quality radiographs can help rule out conditions that may mimic or coexist with an infected shoulder arthroplasty, such as post-arthroplasty rotator cuff failure. It is common practice to obtain a baseline laboratory analysis with white blood cells (WBC) (percentage polymorphonuclear cells), erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP). Computed tomography (CT) scans can be useful to detect osteolysis and to assess remaining bone stock. Ultrasonography and magnetic resonance imaging (MRI) with metal subtraction protocols can determine the presence of local abscesses, effusion, or osteomyelitis. Scintigraphy can detect inflammation but may not be useful in low-grade infections [27, 28].

Synovial fluid analysis from an aspiration or at the time of revision surgery should include cell count, gram stain, cultures for aerobes, anaerobes,

fungi, and mycobacteria and should be held for up to 4 weeks [24]. Unfortunately, a negative culture or gram stain does not always rule out infection. Intraoperatively, at least five biopsy samples should be sent for gram stain and frozen section [29]. Interestingly, increased body mass index, diabetes severity, and asymptomatic bacteriuria or abnormal urinalysis have not been associated with increased rates of infection [12, 30–32].

7.3.2 Instability

7.3.2.1 Instability After Anatomic Total Shoulder Arthroplasty (TSA)

Instability after anatomic total shoulder arthroplasty is a relatively common complication, with a reported prevalence ranging from 1% to 3% [11, 33]. It can occur secondary to insufficient bone stock, inadequate soft tissue balance, component malalignment, or loosening.

Severe primary osteoarthritis, as well as post-capsulorrhaphy arthritis, can lead to excessive acquired retroversion of the native glenoid. Anterior wear is more uncommon, but it can be found in patients with chronic anterior glenohumeral dislocations, glenoid fractures, or rheumatoid arthritis. Failure to identify and correct this deformity can result in glenoid component malalignment and either posterior or anterior instability. Humeral component malpositioning is usually less critical, but it can also play a role in instability.

Diagnosis can be difficult, and a careful physical examination is paramount. In some patients, dislocation of the glenohumeral joint can be obvious radiographically, but in the setting of subluxation, findings will be more subtle. Excessive translation of the humeral head or a positive load-and-shift test can help the examiner in the diagnosis of these cases [34, 35].

Anterior instability after anatomic total shoulder arthroplasty has been reported in 0.9% of the patients [11] and has been associated with subscapularis failure, retroversion of the humeral component of less than 20° [36], anterior glenoid deficiency, and anterior deltoid dysfunction [11]. Of these causes, it is thought that subscapularis dysfunction plays a major role. In these patients, a positive lift-off test and/or belly press test can be found [37].

Management of the subscapularis during the initial surgery remains controversial, as some authors report improved outcomes after a lesser tuberosity osteotomy (LTO) versus a tenotomy or peel technique [38]. This clinical finding has been supported by biomechanical analyses [39, 40]. However, the peel technique or tenotomy of the subscapularis avoids the potential complication of LTO nonunion [41]. To date, there is insufficient high-level clinical evidence to strongly support one technique over the others.

In addition to technique, overstuffing the joint with an excessively large humeral head and medialization of the tendon insertion may lead to failed subscapularis failure. Excessively early mobilization, aggressive physical therapy, or postoperative trauma can also disrupt the subscapularis tendon repair.

Posterior instability after TSA occurs with a similar frequency as anterior instability (1%) [11] and has been associated with soft tissue imbalance. While posterior rotator cuff dysfunction and capsular laxity have been most commonly implicated, component malalignment and posterior bone loss can also play a role [34, 42]. Glenoid retroversion over 20° and humeral component in more than 45° of retroversion have been described as potential causes of posterior instability [36]. Sanchez-Sotelo and colleagues recommended that surgeons pay close attention to the humeral neck cut angle and the subscapularis tendon repair and address any posterior glenoid bone loss to minimize the potential for this complication. In addition, posttraumatic osteoarthritis or preoperative humeral subluxation should be carefully evaluated [34].

Rotator cuff failure is one of the most common complications after anatomic total shoulder replacement. A recent analysis of complications reported to the US Food and Drug Administration (FDA) demonstrated that among all the complications found after 1673 anatomic total shoulder replacements, posterior-superior rotator cuff and subscapularis failure were second only to glenoid component failure, representing 15.4% of all the

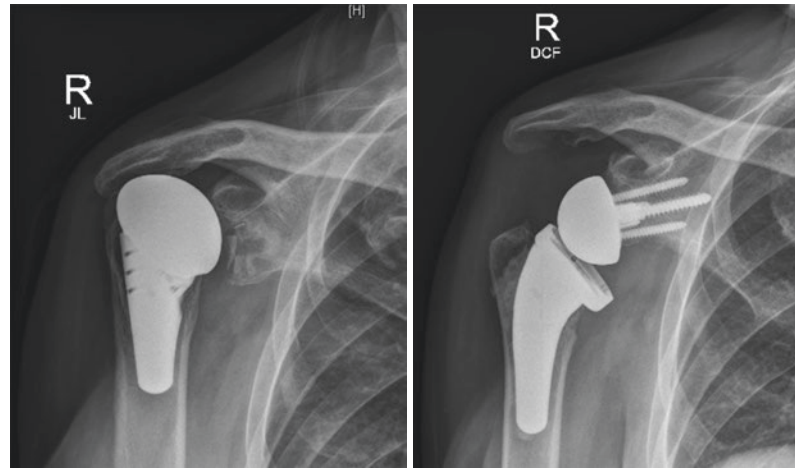

Fig. 7.2 Rotator cuff failure can lead to superior instability. The radiograph on the left demonstrates proximal migration of the humerus, which led to glenoid component fixation failure through the so-called *rocking horse* mechanism. This patient eventually underwent revision surgery to a reverse shoulder arthroplasty (right)

complications [9]. Rotator cuff failure allows the humeral head to migrate proximally, leading to superior instability (Fig. 7.2). Reported in up to 3% of cases [11], superior instability may be the single most common direction of instability following anatomic shoulder arthroplasty.

The rotator cuff can be compromised during the index procedure, specifically if an aggressive humeral resection is performed or if the cut is placed in too much retroversion [43]. Postoperative rotator cuff failure can also occur, with reported rates from 1.3% to 5.8% [11, 37]. Several factors have been found to affect superior instability: fatty infiltration of the infraspinatus, rotator cuff tear size, coracoacromial arch insufficiency, anterior deltoid dysfunction, humeral head overstuffing and malpositioning, and tuberosity nonunion in the setting of fracture [44, 45].

Inferior instability often occurs when the humeral length is not restored and deltoid tensioning is therefore not achieved. This has been reported to be more common after four-part proximal humerus fractures, where the stem can be accidentally seated too low due to a loss of anatomic references. Warren recommends inferior distraction of the humerus to detect this issue intraoperatively. When this maneuver is performed, the head should ideally remain within the upper one-third of the glenoid. Inferior instability may also occur in a setting of an axillary nerve palsy or rotator interval insufficiency in which the dynamic stabilizers are inadequate to hold the glenohumeral joint reduced [42].

7.3.2.2 Instability After Revision Total Shoulder Arthroplasty (RTSA)

Trappey et al. reported an instability rate after RTSA of 5% following primary cases and 8% following revision arthroplasty [46]. The mechanism of dislocation is typically adduction and internal rotation and most commonly occurs within the first 3 months following surgery. Up to 50% of these will have good outcomes with conservative treatment after successful closed reduction. Late dislocations that occur over 3 months after the index procedure often require surgical treatment [47].

Abdelfattah et al. proposed a classification system for instability after reverse total shoulder arthroplasty. They described three main categories: loss of compression, loss of containment, and impingement.

They further divided loss of compression into undersized implants, loss of deltoid contour, humeral height loss, subscapularis deficiency, acromial/scapular fracture, and deltoid dysfunction (Fig. 7.3).

Loss of containment can be subclassified into alteration of depth/radius ratio of the humerosocket and mechanical failure (such as glenosphere-baseplate dissociation, stem fracture, or humerosocket dissociation at the trunnion).

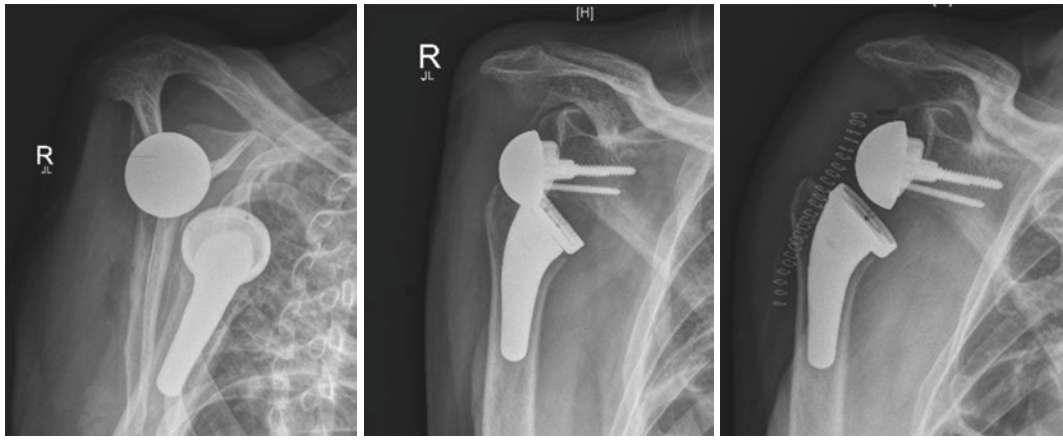

Fig. 7.3 This patient sustained an early dislocation after a reverse total shoulder arthroplasty (left). He underwent a closed reduction, but examination under anesthesia revealed instability of the implant (center). Therefore, revision to a larger glenosphere and a retentive polyethylene was warranted (right)

Impingement can occur in a setting of a large body habitus, with the axillary soft tissue creating a levering-out effect with traction from the weight of the arm. Furthermore, soft tissue or bony impingement can occur in a fracture setting with unreduced retained tuberosities, malunion, or heterotopic ossification; prosthetic malalignment may play a role if the humeral component prematurely contacts the glenoid neck in adduction [48]. This can be modified by changing the glenosphere size, the baseplate placement, offset or tilt or the neck-shaft angle, and version of the humeral component [49].

Trappey and colleagues also found that patients with an irreparable subscapularis had a higher rate of instability [46]. A meta-analysis by Matthewson et al. concluded that subscapularis repair decreases the rate of instability, and in those cases when it cannot be repaired, a lateralized center of rotation results in significantly lower dislocation [50]. Owing to the preservation of the subscapularis tendon insertion, a superior subscapularis-sparing approach may lower the risk of dislocation, with reported rates of instability as low as 0%. However, glenoid exposure and baseplate placement using this approach may be significantly more challenging [51]. Subscapularis involvement in RTSA instability remains controversial in the existing literature, as similar clinical results with or without subscapularis repair have been reported [52].

7.3.3 Component Loosening

7.3.3.1 Anatomic Total Shoulder Arthroplasty Loosening

Prosthetic loosening has been reported to represent 12.4–39% of the complications after anatomic total shoulder arthroplasty [11]. Radiolucencies, calcar resorption, or scapular notchings are common findings after anatomic and reverse shoulder replacement, but not all of them may be clinically relevant. In the presence of pain or gross implant migration, however, further investigation is warranted.

Glenoid component loosening occurs more frequently than aseptic humeral component loosening, representing over 80% of fixation failures [11]. Positive radiographic findings of lucencies about the component vary from 12% to 94% in the literature, but these do not necessarily correlate with clinical findings. In this regard, surgical technique must be meticulous, as it has been suggested that the presence of lucent lines and further frank loosening may be related to the presence of cement on the backside of the glenoid component. This may indicate suboptimal bone preparation of the native glenoid and/or suboptimal seating of the component [53, 54].

Loosening can occur due to uneven force distribution in the setting of glenohumeral instability (the so-called rocking horse mechanism) [55] due to proximal migration of the humeral head in

the setting of rotator cuff failure or due to infection, lack of bone stock, or poor bone fixation. Shoulder biomechanics may also play a role. Compared to other joints, the humeral head appears to have larger "play in the socket," which may explain the faster polyethylene wear that has been found in explanted shoulder liners when compared to equivalent hip inserts [56].

Papadonikolakis found an asymptomatic radiolucency rate of 7.3% per year and symptomatic loosening of 1.2% per year, with more asymptomatic lucencies found in keeled versus pegged implants [57]. Biconcavity of the native glenoid and increased glenoid retroversion may also lead to increased component loosening. Walch et al. found a 21% loosening rate in biconcave glenoids and a 44% complication rate associated to retroversion greater than 27° [58].

Others have found that metal-backed glenoid implants have a revision rate up to three times higher than all-polyethylene components [57]. The Australian registry demonstrated an increased revision rate in both fixed and modular metal-backed glenoid components. They reported a significantly higher revision rate of non-cross-linked vs. cross-linked glenoid components with a hazard ratio of 2.38, but they found no differences in the revision rate between cemented versus hybrid glenoid components in total shoulder arthroplasties [4].

Stem aseptic loosening is much less common than glenoid failure, accounting for 7% of the complications after TSA [11]. In defining stem loosening in non-cemented stems, Sperling described eight radiographic zones around the humeral stem and concluded that a humeral component was "at risk" if a lucent line 2 mm or greater was found in at least three zones [59]. Sanchez-Sotelo used the same parameters to successfully evaluate radiographic loosening in cemented stems [60]. Changes at the bone-implant interface on the humeral side in the presence of a glenoid component have raised concerns about osteolysis and symptomatic loosening in the setting of polyethylene particle debris [45, 60].

7.3.3.2 Reverse Total Shoulder Arthroplasty Loosening

Boileau reported that among all the causes that led to revision surgery after a failed RTSA, 21% were due to humeral side complications. It was the second most common cause of revision after instability. He found that humeral loosening was often related to biological causes (polyethylene wear and metallic debris), in addition to mechanical causes (rotational forces) [47]. Radiographic loosening is rare, with a reported prevalence of less than 1% [61], but proximal humerus bone loss in a proximal humerus fracture setting, for instance, can decrease mechanical strength of the humeral stem leading to an increased risk of humeral-sided failure [62].

Glenoid component loosening is uncommon in the setting of RTSA and can be minimized by careful surgical technique [63]. Avoidance of superior tilt, placement of the baseplate at the most inferior aspect of the glenoid, and achievement of adequate primary stability that allows bone ingrowth are paramount [47, 63].

The influence of scapular notching on glenoid component loosening after reverse shoulder arthroplasty remains controversial, as some series report increased loosening rates related to scapular notching (Fig. 7.4) [14, 64, 65], while others report no association [15, 66, 67]. The use of a superior approach has been reported to increase prevalence of scapular notching [67], which suggests that this approach may indirectly increase the risk of loosening. Lateral and inferior offset of the glenosphere, on the other hand, may minimize radiographic loosening, though some lateralized designs have been reported to potentially lead to a higher rate of component dissociation [68].

7.3.4 Periprosthetic Fractures

Periprosthetic fractures can occur both intraoperatively and postoperatively. The rate of intraoperative periprosthetic fractures has been reported to be between 1.3% and 5.1% [9, 11, 69], with a similar distribution between humeral and glenoid fractures [25]. Female sex, greater number of comorbidities, and a primary diagnosis of posttraumatic osteoarthritis have all been associated to higher rates of periprosthetic fracture [25].

The increased risk in women may be explained by the fact that rheumatoid arthritis and osteoporosis are more common in this population [70].

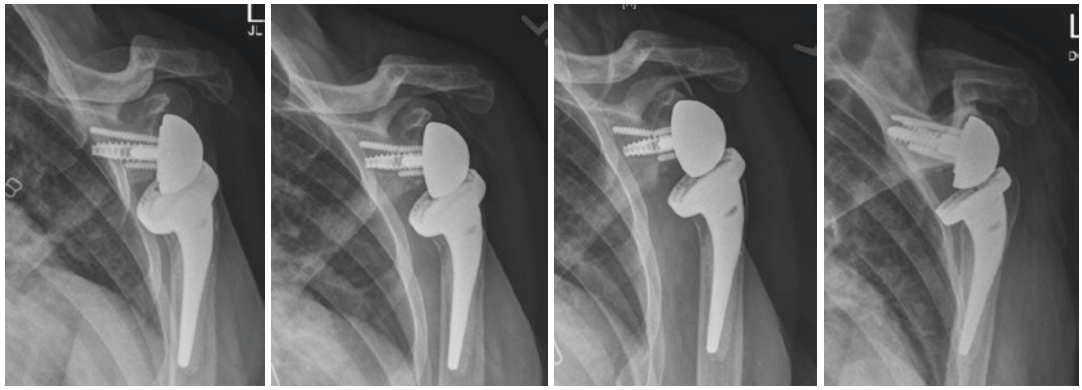

Fig. 7.4 Note the progression of the fixation failure of the baseplate with radiographic evidence of scapular notching and a broken screw and the subsequent glenoid component revision

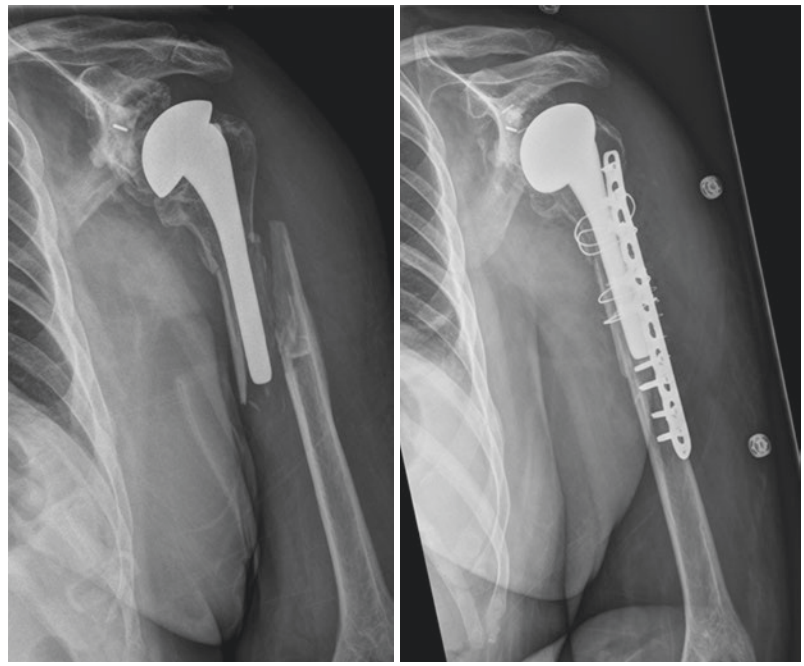

Fig. 7.5 This 64-year-old patient sustained a fall, resulting in a type B fracture, according to the Cofield and Wright classification (left). Intraoperatively, the stem was deemed well-fixed, and therefore open reduction and internal fixation were performed (right)

The relationship between posttraumatic osteoarthritis and intraoperative fracture may be related to the increased joint stiffness in these patients, placing greater torque forces during retraction, which eventually may lead to an intraoperative fracture. Implant stability and fracture pattern may ultimately determine if further intervention is required, such as exchange to a longer stem or open treatment with internal fixation [71].

Postoperative periprosthetic fractures have been reported to occur in 1–3% of cases [72]. Wright and Cofield described the most widely used classification of periprosthetic fractures. According to their classification, type A fractures do not extend beyond the tip of the stem, type B fractures start around the stem and end distal to the tip of it, and type C fractures are distal to the tip of the stem [73].

When evaluating these fractures, implant stability and remaining bone stock will determine further treatment (Fig. 7.5). Campbell described a system to classify bone quality, in which the

bone is considered normal if the ratio between the mid-shaft cortices and the shaft diameter is greater than 50%, mild osteopenia if it is between 25% and 50%, and severe osteopenia if it is below 25%. He found that 75% of the patients in his series of periprosthetic fractures met the definition for osteopenia.

While implant stability is ultimately determined intraoperatively, preoperative radiographs can help the surgeon plan and predict fixation stability. As described earlier, when lucent lines greater than 2 mm are found in at least three of the eight zones described by Sperling, the surgeon may anticipate stem loosening [59]. Implant subsidence or tilt can also help determine the quality of stem fixation before the procedure and allow the surgeon to prepare accordingly.

7.4 Conclusions

While total shoulder replacement has added to our ability to salvage painful shoulders following severe trauma or late-stage arthrosis with and without rotator cuff deficiency, we have also learned that there are limitations to the expectation for a functional, pain-free shoulder. While complications following shoulder arthroplasty can be frustrating for both the patient and surgeon alike, it is unfortunately a reality that all arthroplasty surgeons will encounter at some point in their career.

Recognizing complications and potential failure may be difficult, since many of the signs and symptoms can be nonspecific, such as pain, weakness, and stiffness. However, timely recognition and accurate diagnosis are critical to avoiding a suboptimal outcome. Careful history, physical examination, and good quality imaging studies are essential, but further testing is often necessary and may include blood work, aspiration, CT, MRI or ultrasonography.

Perhaps as important as early diagnosis, however, may be striving to avoid complications altogether. By understanding the common modes of failure, learning to avoid them, and careful patient selection, surgeons may ensure better outcomes for their patients. As we continue to care for ever increasing numbers of patients with end-stage shoulder degeneration and severe trauma, we must continue to exercise judicious indications and meticulous technique and undertake thoughtful review of our outcomes.

References

1. Flatow EL, Harrison AK. A history of reverse total shoulder arthroplasty. Clin Orthop Relat Res. 2011;469:2432–9.
2. Neer CS II. Articular replacement for the humeral head. J Bone Joint Surg Am. 1955;37-A:215–28.
3. Neer CS. Replacement arthroplasty for glenohumeral osteoarthritis. J Bone Joint Surg Am. 1974;56-A:1–13.
4. Australian Orthopaedic Association National Joint Replacement Registry. Hip, knee & shoulder arthroplasty. Annual reports. Adelaide, SA: AOANJRR; 2018.
5. Lübbeke A, Rees JL, Barea C, Combescure C, Carr AJ, Silman AJ. International variation in shoulder arthroplasty: incidence, indication, type of procedure, and outcomes evaluation in 9 countries. Acta Orthop. 2017;88:592–9.
6. NJR. 15th Annual report 2018. Hemel Hempstead: NJR; 2018. National Joint Registry for England, Wales, Northern Ireland and the Isle of Man.
7. Bergen H. Norwegian National Advisory Unit on Arthroplasty and Hip Fractures Norwegian Arthroplasty Register Norwegian Cruciate Ligament Register Norwegian Hip Fracture Register Norwegian Paediatric Hip Register. Trondheim: Norwegian National Advisory Unit; 2018.
8. Lehtimäki K, Rasmussen JV, Mokka J, Salomonsson B, Hole R, Jensen SL, Äärimaa V. Risk and risk factors for revision after primary reverse shoulder arthroplasty for cuff tear arthropathy and osteoarthritis: a Nordic Arthroplasty Register Association study. J Shoulder Elbow Surg. 2018;27:1596–601.
9. Somerson JS, Hsu JE, Neradilek MB, Matsen FA. Analysis of 4063 complications of shoulder arthroplasty reported to the US Food and Drug Administration from 2012 to 2016. J Shoulder Elbow Surg. 2018;27:1978–86.
10. Gonzalez J-F, Alami GB, Baque F, Walch G, Boileau P. Complications of unconstrained shoulder prostheses. J Shoulder Elbow Surg. 2011;20:666–82.
11. Bohsali KI, Wirth MA, Rockwood CA. Complications of total shoulder arthroplasty. J Bone Joint Surg Am. 2006;88-A:2279–92.
12. Richards J, Inacio MCS, Beckett M, Navarro RA, Singh A, Dillon MT, Sodl JF, Yian EH. Patient and procedure-specific risk factors for deep infection after primary shoulder arthroplasty. Clin Orthop Relat Res. 2014;472:2809–15.

13. Gerber C, Pennington SD, Nyffeler RW. Reverse total shoulder arthroplasty. J Am Acad Orthop Surg. 2009;17:284–95.
14. Werner CML, Steinmann PA, Gilbart M, Gerber C. Treatment of painful pseudoparesis due to irreparable rotator cuff dysfunction with the Delta III reverse-ball-and-socket total shoulder prosthesis. J Bone Joint Surg Am. 2005;87:1476–86.
15. Zumstein MA, Pinedo M, Old J, Boileau P. Problems, complications, reoperations, and revisions in reverse total shoulder arthroplasty: a systematic review. J Shoulder Elbow Surg. 2011;20:146–57.
16. Walch G, Bacle G, Lädermann A, Nové-Josserand L, Smithers CJ. Do the indications, results, and complications of reverse shoulder arthroplasty change with surgeon's experience? J Shoulder Elbow Surg. 2012;21:1470–7.
17. Howe CR, Gardner GC, Kadel NJ. Perioperative medication management for the patient with rheumatoid arthritis. J Am Acad Orthop Surg. 2006;14:544–51.
18. Luessenhop CP, Higgins LD, Brause BD, Ranawat CS. Multiple prosthetic infections after total joint arthroplasty: risk factor analysis. J Arthroplasty. 1996;11:862–8.
19. Bala A, Penrose CT, Visgauss JD, Seyler TM, Randell TR, Bolognesi MP, Garrigues GE. Total shoulder arthroplasty in patients with HIV infection: complications, comorbidities, and trends. J Shoulder Elbow Surg. 2016;25:1971–9.
20. Hatta T, Werthel JD, Wagner ER, Itoi E, Steinmann SP, Cofield RH, Sperling JW. Effect of smoking on complications following primary shoulder arthroplasty. J Shoulder Elbow Surg. 2017;26:1–6.
21. Everhart JS, Bishop JY, Barlow JD. Medical comorbidities and perioperative allogeneic red blood cell transfusion are risk factors for surgical site infection after shoulder arthroplasty. J Shoulder Elbow Surg. 2017;26:1922–30.
22. Werthel JD, Hatta T, Schoch B, Cofield R, Sperling JW, Elhassan BT. Is previous nonarthroplasty surgery a risk factor for periprosthetic infection in primary shoulder arthroplasty? J Shoulder Elbow Surg. 2017;26:635–40.
23. Torrens C, Marí R, Alier A, Puig L, Santana F, Corvec S. Cutibacterium acnes in primary reverse shoulder arthroplasty: from skin to deep layers. J Shoulder Elbow Surg. 2019;28:839–46.
24. Pottinger P, Butler-Wu S, Neradilek MB, Merritt A, Bertelsen A, Jette JL, Warme WJ, Matsen FA. Prognostic factors for bacterial cultures positive for Propionibacterium acnes and other organisms in a large series of revision shoulder arthroplasties performed for stiffness, pain, or loosening. J Bone Joint Surg Am. 2012;94:2075–83.
25. Singh JA, Sperling JW, Schleck C, Harmsen WS, Cofield RH. Peri-prosthetic infections after shoulder hemiarthroplasty. J Shoulder Elbow Surg. 2012;21:1304–9.
26. Weber P, Utzschneider S, Sadoghi P, Andress HJ, Jansson V, Müller PE. Management of the infected shoulder prosthesis: a retrospective analysis and review of the literature. Int Orthop. 2011;35:365–73.
27. Topolski MS, Chin PYK, Sperling JW, Cofield RH. Revision shoulder arthroplasty with positive intraoperative cultures: the value of preoperative studies and intraoperative histology. J Shoulder Elbow Surg. 2006;15:402–6.
28. Alesi D, Roberti di Sarsina T, Zaffagnini S, Marcheggiani Muccioli G, Lullini G, Rotini R, Cammisa E, Fratini S, Rinaldi V, Guerra E. Diagnosis and treatment of infected shoulder arthroplasty: current concepts review. Joints. 2018;6:173–6.
29. Fink B, Sevelda F. Periprosthetic joint infection of shoulder arthroplasties: diagnostic and treatment options. Biomed Res Int. 2017;2017:1–10.
30. Gómez-Ochoa SA, Espín-Chico BB, García-Rueda NA, Vega-Vera A, Osma-Rueda JL. Risk of surgical site infection in patients with asymptomatic bacteriuria or abnormal urinalysis before joint arthroplasty: systematic review and meta-analysis. Surg Infect (Larchmt). 2019;20:159–66.
31. McElvany MD, Chan PH, Prentice HA, Paxton EW, Dillon MT, Navarro RA. Diabetes disease severity was not associated with risk of deep infection or revision after shoulder arthroplasty. Clin Orthop Relat Res. 2019;477:1358. https://doi.org/10.1097/CORR.0000000000000642.
32. Wagner ER, Houdek MT, Schleck C, Harmsen WS, Sanchez-Sotelo J, Cofield R, Sperling JW, Elhassan BT. Increasing body mass index is associated with worse outcomes after shoulder arthroplasty. J Bone Joint Surg Am. 2017;99:929–37.
33. Bohsali KI, Bois AJ, Wirth MA. Complications of shoulder arthroplasty. J Bone Joint Surg Am. 2017;99:256–69.
34. Sanchez-Sotelo J, Sperling JW, Rowland CM, Cofield RH. Instability after shoulder arthroplasty: results of surgical treatment. J Bone Joint Surg Am. 2003;85:622–31.
35. Moeckel B, Altchek DW, Warren RF, Wickiewicz TL, Dines DM. Instability of the shoulder after arthroplasty. J Bone Joint Surg Am. 1993;75:492–7.
36. Wirth MA, Rockwood CA. Current concepts review - complications of total shoulder-replacement arthroplasty. J Bone Joint Surg Am. 2016;78:603–16.
37. Miller BS, Joseph TA, Noonan TJ, Horan MP, Hawkins RJ. Rupture of the subscapularis tendon after shoulder arthroplasty: diagnosis, treatment, and outcome. J Shoulder Elbow Surg. 2005;14:492–6.
38. Jackson JD, Cil A, Smith J, Steinmann SP. Integrity and function of the subscapularis after total shoulder arthroplasty. J Shoulder Elbow Surg. 2010;19:1085–90.
39. Van den Berghe GR, Nguyen B, Patil S, D'Lima DD, Mahar A, Pedowitz R, Hoenecke HR. A biomechanical evaluation of three surgical techniques

for subscapularis repair. J Shoulder Elbow Surg. 2008;17:156–61.
40. Ponce BA, Ahluwalia RS, Mazzocca AD, Gobezie RG, Warner JJP, Millett PJ. Biomechanical and clinical evaluation of a novel lesser tuberosity repair technique in total shoulder arthroplasty. J Bone Joint Surg Am. 2005;87:1–8.
41. Caplan JL, Whitfield B, Neviaser RJ. Subscapularis function after primary tendon to tendon repair in patients after replacement arthroplasty of the shoulder. J Shoulder Elbow Surg. 2009;18:193–6.
42. Warren RF, Coleman SH, Dines JS. Instability after arthroplasty: the shoulder. J Arthroplasty. 2002;17:28–31.
43. Pearl ML, Volk AG. Retroversion of the proximal humerus in relationship to prosthetic replacement arthroplasty. J Shoulder Elbow Surg. 1995;4:286–9.
44. Young AA, Walch G, Pape G, Gohlke F, Favard L. Secondary rotator cuff dysfunction following total shoulder arthroplasty for primary glenohumeral osteoarthritis: results of a multicenter study with more than five years of follow-up. J Bone Joint Surg Am. 2012;94:685–93.
45. Haines JF, Trail IA, Nuttall D, Birch A, Barrow A. The results of arthroplasty in osteoarthritis of the shoulder. J Bone Joint Surg Br. 2006;88-B:496–501.
46. Trappey GJ, O'Connor DP, Edwards TB. What are the instability and infection rates after reverse shoulder arthroplasty? Clin Orthop Relat Res. 2011;469:2505–11.
47. Boileau P. Complications and revision of reverse total shoulder arthroplasty. Orthop Traumatol Surg Res. 2016;102:S33–43.
48. Abdelfattah A, Otto RJ, Simon P, Christmas KN, Tanner G, LaMartina J, Levy JC, Cuff DJ, Mighell MA, Frankle MA. Classification of instability after reverse shoulder arthroplasty guides surgical management and outcomes. J Shoulder Elbow Surg. 2018;27:e107–18.
49. Barco R, Savvidou OD, Sperling JW, Sanchez-Sotelo J, Cofield RH. Complications in reverse shoulder arthroplasty. EFORT Open Rev. 2016;1:72–80.
50. Matthewson G, Kooner S, Kwapisz A, Leiter J, Old J, MacDonald P. The effect of subscapularis repair on dislocation rates in reverse shoulder arthroplasty: a meta-analysis and systematic review. J Shoulder Elbow Surg. 2019;28:989–97.
51. Mole D, Favard L. Excentered scapulohumeral osteoarthritis [article in French]. Rev Chir Orthop Reparatrice Appar Mot. 2007;93:37–94.
52. Clark JC, Ritchie J, Song FS, Kissenberth MJ, Tolan SJ, Hart ND, Hawkins RJ. Complication rates, dislocation, pain, and postoperative range of motion after reverse shoulder arthroplasty in patients with and without repair of the subscapularis. J Shoulder Elbow Surg. 2012;21:36–41.
53. Lazarus MD, Jensen KL, Southworth C, Matsen FA 3rd. The radiographic evaluation of keeled and pegged glenoid component insertion. J Bone Joint Surg Am. 2002;84:1174–82.
54. Hsu JE, Hackett DJJ, Vo KV, Matsen FA 3rd. What can be learned from an analysis of 215 glenoid component failures? J Shoulder Elbow Surg. 2018;27:478–86.
55. Franklin JL, Barrett WP, Jackins SE, Matsen FA. Glenoid loosening in total shoulder arthroplasty. J Arthroplasty. 1988;3:39–46.
56. Kocsis G, Payne CJ, Wallace A, McNally D. Wear analysis of explanted conventional metal back polyethylene glenoid liners. Med Eng Phys. 2018;59:1–7.
57. Papadonikolakis A, Neradilek MB, Matsen FA. Failure of the glenoid component in anatomic total shoulder arthroplasty. J Bone Joint Surg Am. 2013;95:2205–12.
58. Walch G, Moraga C, Young A, Castellanos-Rosas J. Results of anatomic nonconstrained prosthesis in primary osteoarthritis with biconcave glenoid. J Shoulder Elbow Surg. 2012;21:1526–33.
59. Sperling JW, Cofield RH, O'Driscoll SW, Torchia ME, Rowland CM. Radiographic assessment of ingrowth total shoulder arthroplasty. J Shoulder Elbow Surg. 2000;9:507–13.
60. Sanchez-Sotelo J, O'Driscoll SW, Torchia ME, Cofield RH, Rowland CM. Radiographic assessment of cemented humeral components in shoulder arthroplasty. J Shoulder Elbow Surg. 2001;10:526–31.
61. Gilot G, Alvarez-Pinzon AM, Wright TW, Flurin PH, Krill M, Routman HD, Zuckerman JD. The incidence of radiographic aseptic loosening of the humeral component in reverse total shoulder arthroplasty. J Shoulder Elbow Surg. 2015;24:1555–9.
62. Cuff D, Levy JC, Gutiérrez S, Frankle MA. Torsional stability of modular and non-modular reverse shoulder humeral components in a proximal humeral bone loss model. J Shoulder Elbow Surg. 2011;20:646–51.
63. Boileau P, Melis B, Duperron D, Moineau G, Rumian AP, Han Y. Revision surgery of reverse shoulder arthroplasty. J Shoulder Elbow Surg. 2013;22:1359–70.
64. Lévigne C, Boileau P, Favard L, Garaud P, Molé D, Sirveaux F, Walch G. Scapular notching in reverse shoulder arthroplasty. J Shoulder Elbow Surg. 2008;17:925–35.
65. Vanhove B, Beugnies A. Grammont's reverse shoulder prosthesis for rotator cuff arthropathy. A retrospective study of 32 cases. Acta Orthop Belg. 2004;70:219–25.
66. Wall B, Nové-Josserand L, O'Connor DP, Edwards TB, Walch G. Reverse total shoulder arthroplasty: a review of results according to etiology. J Bone Joint Surg Am. 2007;89:1476–85.
67. Melis B, DeFranco M, Lädermann A, Molé D, Favard L, Nérot C, Maynou C, Walch G. An evaluation of the radiological changes around the Grammont reverse geometry shoulder arthroplasty after eight to 12 years. J Bone Joint Surg Br. 2011;93-B:1240–6.
68. Cusick MC, Hussey MM, Steen BM, Hartzler RU, Clark RE, Cuff DJ, Cabezas AF, Santoni BG, Frankle MA. Glenosphere dissociation after reverse

shoulder arthroplasty. J Shoulder Elbow Surg. 2015;24:1061–8.
69. Wagner ER, Houdek MT, Elhassan BT, Sanchez-Sotelo J, Cofield RH. Sperling JW (2015) What are risk factors for intraoperative humerus fractures during revision reverse shoulder arthroplasty and do they influence outcomes? Clin Orthop Relat Res. 2015;473:3228–34.
70. Campbell JT, Moore RS, Iannotti JP, Norris TR, Williams GR. Periprosthetic humeral fractures: mechanisms of fracture and treatment options. J Shoulder Elbow Surg. 1998;7:406–13.
71. García-Fernández C, Lópiz-Morales Y, Rodríguez A, López-Durán L, Martínez FM. Periprosthetic humeral fractures associated with reverse total shoulder arthroplasty: incidence and management. Int Orthop. 2015;39:1965–9.
72. Williams GRJ, Iannotti JP. Management of periprosthetic fractures: the shoulder. J Arthroplasty. 2002;17:14–6.
73. Wright TW, Cofield RH. Humeral fractures after shoulder arthroplasty. J Bone Joint Surg Am. 1995;77:1340–6.

8 Revision Total Shoulder Arthroplasty: Surgical Technique

Raul Barco, Alfonso Vaquero-Picado, and Samuel Antuña

8.1 Introduction

Revision arthroplasty of any joint is always challenging. In the shoulder, were the soft tissue is so vital for joint stability and mobility, it poses an extra challenge. The advent of reverse shoulder arthroplasty and platform arthroplasty systems has changed the way prior failed anatomic arthroplasty is managed, but they are challenging procedures and subject to a high number of complications. Glenoid or humeral bone loss, the presence of a well-fixed stem, the increasing incidence of periprosthetic fractures, and the existence of instability pose distinct situations that must be addressed during revision surgery. The surgeon facing this kind of operations must be facile with a significant number of procedures to expeditiously address these situations. There has been a trend toward increasing the use of reverse shoulder arthroplasty in the revision setting due to the fact that many of these patients have compromised cuff function. We will review some of the current problems and, hopefully, some of the possible solutions.

8.2 Preoperative Planning

Preoperative planning helps define the strategy for revision surgery. Quoting Benjamin Franklin, "Failure to prepare is preparing to fail." The deltoid must be explored for axillary nerve injury as an injury to the nerve changes patient's expectations and results. Damage to the terminal branches of the deltoid, which affect the most anterior part of the deltoid, may, in itself, not compromise the results of the surgery. Computed tomography (CT) scan evaluation to address possible bone loss is critical. Ultrasound can be used to assess the state of the remaining rotator cuff. Magnetic resonance imaging (MRI) in the presence of previous arthroplasties is less useful due to the presence of signal interference, even with the use of modified protocols.

Previous skin incisions must be explored. Adhesion of skin to deeper structures must be examined. We favor long deltopectoral lateral skin incisions, and we prefer incorporating the old incision into the planned approach as much as possible.

Most revision surgery patients are affected to some extent with stiffness, so appropriate releases must be performed. Bone loss and soft tissue contracture are the most common reasons for stiffness and must be addressed. Stiffness may

R. Barco (✉)
Department of Orthopedic Surgery, "La Paz" University Hospital, Madrid, Spain

Upper Limb Unit, "La Paz" University Hospital, Madrid, Spain

A. Vaquero-Picado · S. Antuña
Department of Orthopedic Surgery, "La Paz" University Hospital, Madrid, Spain

E. C. Rodríguez-Merchán (ed.), *Revision Total Joint Arthroplasty*,
https://doi.org/10.1007/978-3-030-24773-7_8

Table 8.1 Causes for revision surgery after hemiarthroplasty

- Infection
- Stiffness
- Instability
- Rotator cuff tearing or muscle deficiency
- Deltoid detachment or paralysis
- Greater tuberosity problems (nonunion, resorption)
- Humeral loosening
- Component malposition
- Glenoid arthritis

increase the risk of intraoperative fracture, and meticulous dissection of the surrounding soft tissue is necessary (Table 8.1). Occasionally, an extended anterolateral approach may be required to expose the humerus while minimizing the risk of intraoperative fracture.

Most of the shoulder revision surgery is due to glenoid failure, many of which have underlying anterior or superior instability. This compromised cuff function compromises the results of a new total anatomic shoulder, so there has been a trend toward revision using reverse shoulder arthroplasty. While the number of complications has been initially high, the improved understanding knowledge of how this implant works and new improvements in implant design and surgical technique has fostered its use in revision situations [1–3].

The appropriate implants must be available, including long stems, big heads, and metaglenes with long pegs and augmented baseplates. A high-speed burr and a flexible saw with a set of osteotomes may be necessary to revise the humeral implant, as well as a cerclage system to fix the osteotomy. Small screws may be necessary to graft the glenoid, and plates might be required in case of an allograft-prosthetic composite type of reconstruction for the proximal humerus or a periprosthetic fracture.

8.3 Surgical Technique

8.3.1 Anesthesia and Patient Positioning

We favor general anesthesia with the use of an interscalene block for pain management with hypotensive measures to decrease the risk of bleeding. Additionally, we use tranexamic acid intravenously or at the end of the procedure, depending on patients' characteristics.

We place our patients in the beach chair position. The scapula must be accessible, and putting the patient very lateral on the table or using a specific shoulder surgical table can achieve this. We use a static adjustable stand to place the arm, but pneumatic specific arm holders or a simple Mayo stand can be used. Changing the arm position during the procedure as well as the height or inclination of the surgical table might be helpful.

8.3.2 Approach

In case of revision surgery, most patients will benefit from a long deltopectoral approach. Ideally, the incision will be placed lateral to the conjoined tendon, but we generally try to incorporate the previous skin incision. If sinus tracts are present, the whole sinus tract is removed. Staining the sinus tract with methylene blue might be helpful to determine the extent of the tract. A long deltopectoral approach benefits from access to the distal insertion of the deltoid and humerus and can be extended anterolaterally to expose the whole humerus if necessary. In cases of distal extension, it is safer to dissect and control the radial nerve at the beginning of the procedure. A proximal extension can be performed up to the clavicle for resection of the distal clavicle, which can serve as bony autograft if needed.

We tend to leave the cephalic vein in the proximal part of the interval so it can guide the dissection, should revision surgery be necessary. Dissecting the cephalic vein and protecting it are probably best for the patient to avoid hand swelling. Finding the deltopectoral interval can be difficult in revision cases. To be most efficient in cases where the vein is not found, or the deltopectoral interval is not evident, one can palpate the acromioclavicular joint and slide medially 2–3 cm, which marks the medial end of the deltoid muscle and then progress distally toward the deltoid insertion. Where to place the vein is controversial. Our preference is to place the vein

medial in primary cases, which requires ligation of the vessels feeding the deltoid. In revision cases our preference is to place the vein laterally just in case there is a need to extend the dissection distally so it does not get in the way. A Hohman retractor is placed over the coracoid and under the distal part of the deltoid to provide initial tension for further subdeltoid dissection.

Subdeltoid release of adhesions is usual, and we perform this by placing the arm in abduction to decrease the tension of the deltoid, and we then place the arm in progressive internal rotation until we have freed all adhesions. We must be careful to protect the axillary nerve at the lower part of the inner deltoid as we are dissecting these adhesions.

By using a long deltopectoral approach, we can perform a limited dissection of the distal insertion of the deltoid if we need access to the proximal part of the humerus, which is rather safe and does not compromise postoperative function. If we feel the deltoid is very scarred and rigid and can suffer during the approach, it is probably safer to extend the approach proximally and detach the deltoid from the clavicle (anteromedial approach) (Fig. 8.1) [4]. The detachment is performed from medial to lateral and requires periosteal dissection to preserve the deltoid fascia. On occasion releasing only the first 2 cm of this extensive approach is enough to decrease tension in the deltoid. A secure transosseous fixation and use of an abduction brace postoperatively are recommended to achieve healing of the deltoid. Other reasons to use this extended deltoid include the realization of a frail deltoid, to minimize the stress of an osteopenic humerus during the approach, and to gain better access to expose the glenoid or the rotator cuff.

The next step is to perform subcoracoid dissection, as it is frequent to find adhesions that can limit the range of motion in external rotation. Careful dissection is necessary as excessive traction might injure the axillary nerve or the brachial plexus and extension medial to the coracoid are not advised.

How to proceed from here depends on the cause of failure and our treatment strategy. If we are planning a revision to an anatomical total shoulder, delicate handling of the rotator cuff is warranted. We will then perform a tenotomy of the subscapularis. If the long head of the biceps is still present, we tenodese it at the proximal part of the groove so it can serve as an adjunct for later repair of the subscapularis. Performing an adequate release of the subscapularis is important for tension-free repair although it is compromised. Releasing adhesions between the posterior part of the subscapularis and the anterior glenoid and capsule is critical not only to obtain the maximum range of motion but to gain control of the anterior wall of the glenoid vault which can be useful for intraoperative orientation for glenoid instrumentation.

We then go on to release the proximal humerus until we can perform a safe external rotation of

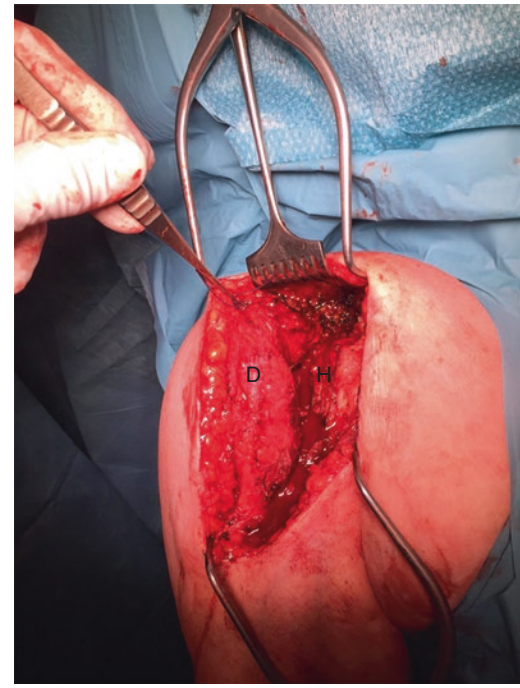

Fig. 8.1 Picture of an anteromedial approach to the shoulder in a revision shoulder case. In cases of scarring or stiffness, it can be difficult to get adequate exposure of the glenoid without injuring the deltoid. Performing an anteromedial approach is an excellent option to obtain improved exposure in revision cases. The anterior deltoid is released from its insertion in the clavicle (white dotted line). In the picture we observe the deltoid (D), and the medial insertion is being held with the forceps. H = humerus

the arthroplasty to gain access to the head of the arthroplasty. In cases of pre-existing stiffness, external rotation is performed with caution; otherwise we can produce a fracture. If the approach to the humerus is compromised, performing an anteromedial approach is justified. Most systems have instruments to disengage the humeral head from the stem, but in case of finding a non-modular stem, we attempt to disimpact it from underneath with the use of a bolt and a mallet, which has to be done with care because there is a risk of fracturing the greater tuberosity. Once the head is removed, we gain more access to complete the capsulotomy in the humerus. At this point, there is enough space to work around the glenoid to achieve the necessary capsulotomy.

8.3.3 Glenoid Component

Failure of the glenoid implant due to loosening is the most frequent cause for revision of glenoid failure after total shoulder arthroplasty (TSA) and is typically associated with osteolysis and bone loss. Bone loss can be due to primary pre-existing asymmetric wear, aseptic loosening as just mentioned, and unintended bone loss when performing the explantation of the prior glenoid. As outlined by Antuña et al., these defects can be contained or uncontained and classified in terms of the quantity of the defect in mild, moderate, or severe [5]. In 17 out of 48 shoulders, the authors found associated instability. While radiologic lucent lines around the glenoid component are frequent, the definition of glenoid failure is somewhat equivocal. Most patients can have glenoid implant mobilization and be relatively asymptomatic. The decision to operate on a mobilized glenoid is based on clinical symptoms, radiologic signs, desires and volition of the patient, and possible procedures and outcomes.

If the soft tissue are in good condition, glenoid revision can be attempted with a new glenoid implant. Implanting a new glenoid component achieves better pain relief than not revising the implant [5]. However, associated bone loss may preclude insertion at the same surgical procedure and can be deferred until graft consolidation. Reaming the remaining glenoid to achieve a congruous surface and trying to center the humeral head on the glenoid are the goals of the procedure although bone grafting is preferable, as it rebuilds glenoid bone stock and can improve our chances to implant a new glenoid component.

If the surrounding tissues are not in perfect condition, revision to a reverse shoulder implant is probably preferable. In cases without glenoid loss, revision to a reverse shoulder arthroplasty is a straightforward procedure. We use a saw to cut the polyethylene in sectors, and we use a rongeur to take them out. We then use a reamer to prepare the glenoid surface, and the pegs can be overdrilled. Implantation of the metaglene is then carried out (Fig. 8.2).

If there is a bone defect of less than 2 mm and the shoulder offset is restored by the implant, no bone graft is needed. In cases of a peripheral glenoid defect with a stable implant and more than 50% contact in native bone, structural autograft or allograft can be used to reconstruct the defect. Cases with more than 50% of a peripheral defect may need a structural autograft form the iliac crest. In cases of a central defect with more than 30% contact, morselized autograft or allograft can be used to improve contact. If the contact of the implant with native bone is <30%, iliac crest autograft, distal clavicle, or allograft can be used [6]. The use of a reverse design produces significant forces on the glenoid, and the graft can be performed as a single or a staged procedure; first, the graft is fixed with screws, and on a second procedure after graft healing, the baseplate is implanted (Fig. 8.3) [7].

8.3.4 Stem Exchange

Stem exchange can be a very challenging part of the procedure. Platform systems may significantly reduce the time and burden of a revision stem procedure. While the rate of stem survival at 10 years is greater than 90% and the risk of loosening is circa 5%, the rate of stem exchange during surgery approaches 50% during revision

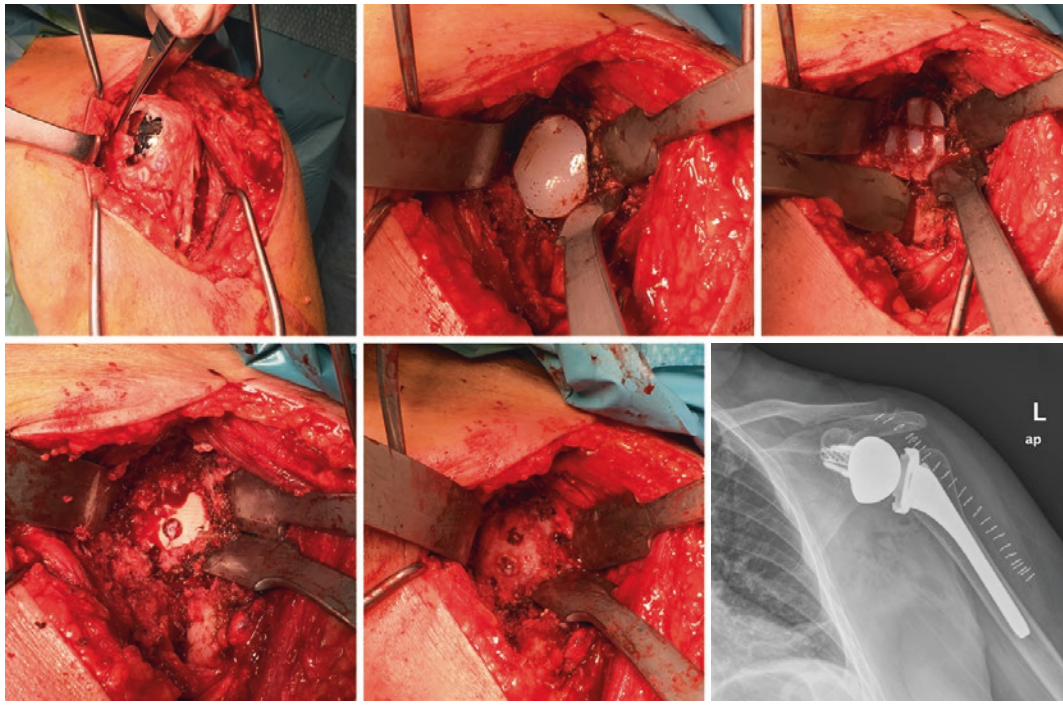

Fig. 8.2 Glenoid component revision: Picture of a revision case after subscapularis failure after total shoulder arthroplasty (upper left). An adequate exposure is crucial to visualize a multipegged polyethylene glenoid (upper center). The glenoid is sawed until the glenoid face in quadrants (upper left), which are then removed with a rongeur (bottom left). A rest of cement is removed with osteotomes, and the glenoid is reamed to prepare it for placement of a metaglene (bottom center). The final X-ray shows a reverse shoulder arthroplasty. In this case the humerus was not exchanged and due to the modularity, the humeral head and a reverse tray were implanted which makes for an easier case

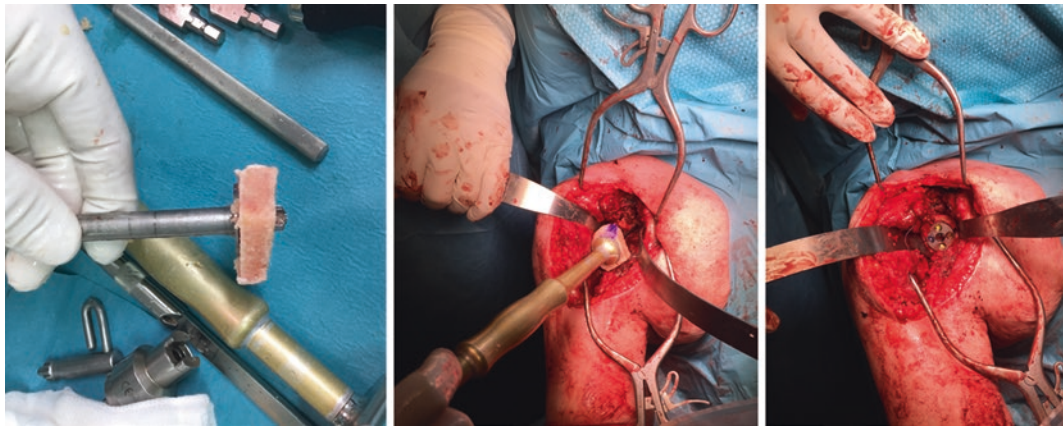

Fig. 8.3 Implanting a metaglene after glenoid bone grafting. In cases with glenoid erosion or a central bone defect, one option is to perform a glenoid bone graft, in this case, using a distal femoral condyle (left). The metaglene is impacted into the glenoid vault (center) and fixed with a central screw and peripheral screws (right)

shoulder arthroplasty [8]. The reasons for these are unclear, but version, height, and access to the glenoid can all precipitate the revision. The reasons for exchanging the stem must be compelling because it is related to an increased amount of intraoperative complications including cement extrusion, intraoperative humeral shaft fracture, and tuberosity fractures.

In a cemented stem, we extract the humeral stem by impacting it from distal to proximal into the collar. If a collar is absent, we can perform a notch with a high-speed burr in the medial aspect of the stem and can then vertically impact into this notch from south to north. A best-case scenario features the prostheses coming out with the whole mantle of cement. If the stem doesn't come out, a longitudinal humerus split for the length of the prostheses is performed through the anterolateral cortex and the cement mantle typically reaching to the tip of the stem. Very carefully, osteotomes are used to crack this split open, and the stem is freed from the cement mantle and extracted carefully. However, when the stem is fully textured, it is probably safer to perform an anterior humeral window. The extent of the window starts proximally below the subscapularis insertion and extends to the end of the prostheses. A 1-cm-wide osteotomy including the insertion of the pectoralis major is favored. We prefer to drill holes at the corners to dissipate any energy created during the extraction to minimize the risk of fracture. A saw is used to connect the corners, and the window is elevated very carefully with the sequential use of osteotomes [9, 10].

When cement is retained, we must weigh the benefit of extracting all the cement and placing a longer stem, which requires time and effort and can compromise remaining stock against the possibility of implanting a shorter stem with a cement-in-cement technique. This technique has been proved safe and reliable at short follow-up in a group of patients at the Mayo Clinic [11].

Removing a well-fixed uncemented stem can be a grueling experience depending on the texturing and the extent of the texturing of the stem. More modern stems are porous coated only proximally, and this will facilitate removal. Otherwise, the need for an osteotomy dramatically increases. The first step is to disrupt the interface between the host bone and the prostheses while minimizing bone stock loss. We favor using a small burr and a saw or flexible osteotomies circumferentially in the proximal part of the humerus. We then try to extract the humerus with the aid of the stem's specific extractor or a fish-mouth clamp and a mallet. If this is unsuccessful, a longitudinal osteotomy is performed with the use of a saw form the proximal part to the tip of the stem, and it is then pried opening carefully with the use of osteotomes (Fig. 8.4). After the stem has been extracted, the osteotomy is closed and secured with the aid of wire cerclage, and surgery is continued to insert another humeral component. Attention to correct version, height of the entire arm, and relationship with the greater tuberosity is advised to provide for the best outcome. Adequate reconstruction is based on the relative length of the deltoid to maximize stability and function.

Most typically bone loss will be minimal but will facilitate ease of extraction of the humeral implant. If there is a residual cement mantle, ideally we should remove the cement mantle, but this can be a time-consuming and challenging process, and there is the risk of producing humeral fractures. A hip cement extraction set is helpful in these situations. Some surgeons are fond of ultrasound to help remove cement, but there is a risk of injuring the radial nerve. If the bone-cement mantle is stable, one option is to roughen the cement mantle and cement a new humeral component. This "cement-in-cement technique" has proven successful at midterm follow-up. Wagner et al. reported on the use of this technique in revision surgery in 38 patients [11]. Specifically looking at the performance of the new implant, there was a new revision surgery in three patients at 3.7 years of follow-up. One patient was revised for humeral loosening, one patient for instability and glenoid loosening, and one for a periprosthetic humeral fracture, giving an overall implant revision-free survival at 2 years and 5 years of 95% and 91%, respectively. Additionally, there was one "at-risk" humeral component with moderate subsidence that was not revised at final follow-up and two

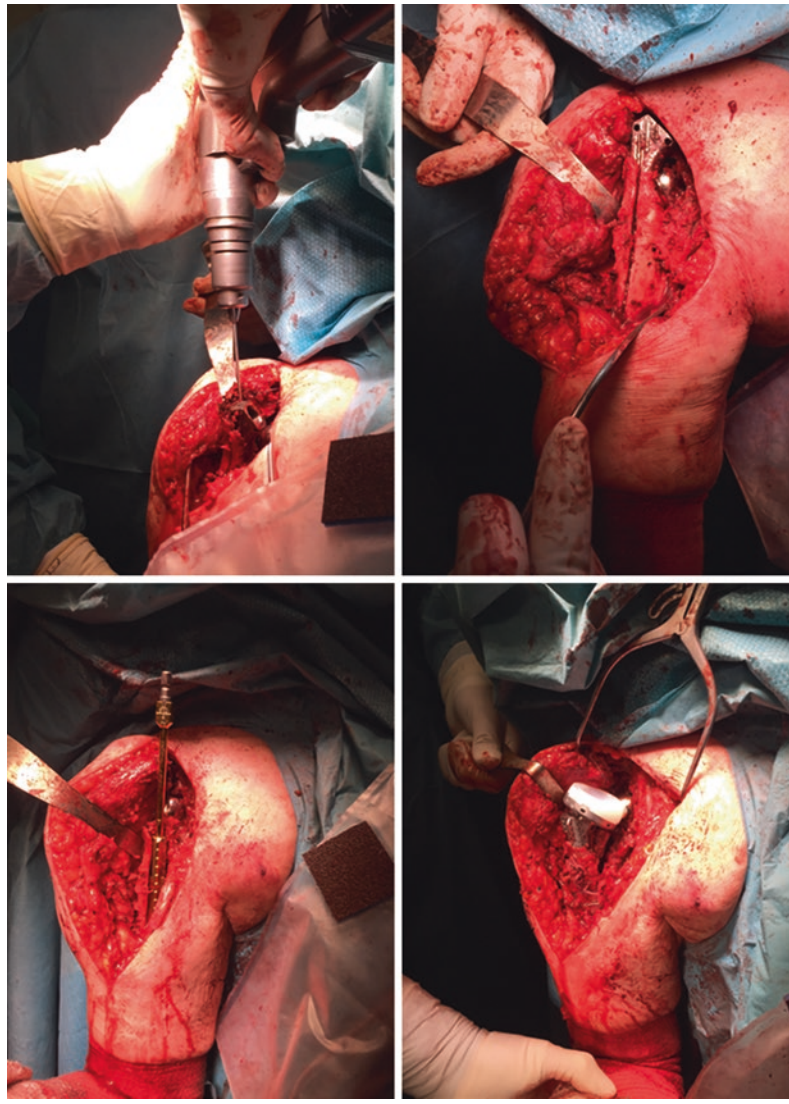

Fig. 8.4 Exchanging a distally cemented humeral stem. Modern stems have specific impactors to explant a humeral stem. Proximal ingrowth or cement may difficult the explantation of a humeral stem. The use of flexible saws or a motorized router circumferentially around the humeral stem is a safe and easy way to control proximally porous coated stems (upper left). Longitudinal osteotomies are somewhat necessary to disrupt the ingrowth or the cement mantle, which allow for safe removal of the stem. Osteotomes are useful to pry open the osteotomy (upper right). If unsuccessful, a humeral window allows for a safe extraction of the stem. Removal of the distal cement and reaming are performed, and wires are passed circumferentially to close the osteotomy prior to cementation (bottom left). After implantation of the final stem, there is mild proximal humeral loss, but the implant is stable (bottom right)

additional grade 3 humeral lucencies without subsidence. The authors reported seven (18%) non-displaced greater tuberosity fractures that happened in every case during stem removal.

Bone loss is typically seen proximally and depending on the extent, and quality of residual bone loss can be managed by neglecting it with or without exchanging the stem or by reconstructing it with an allograft-prosthesis composite (APC) reconstruction or a tumor prostheses. Typically, defects of less than 5 cm with good-quality residual bone can be safely revised with a

new humeral stem, while defects greater than 5 cm and bad-quality bone are revised with an APC technique.

Budge et al. in a series of 15 patients with an average proximal humeral bone loss of 38 mm (range, 26–72 mm) treated with modular implants without the use of allografts reported 87% of patient satisfaction with the procedure with improved function. They did not see loosening or subsidence at a minimum of 2 years and observed a fracture of a modular humeral stem, which inclined them to conclude that monobloc implants could decrease the risk of implant fracture [12]. Stephens et al. also recommended the use of a monobloc stem in cases of revision without the need for allograft in case of moderate humeral bone loss (mean, 3.3 cm) [13].

Some surgeons are using tumor implants for proximal humeral bony defects as it is a more straightforward and yet effective way of treatment [14]. Reconstruction of the humeral offset with a lateralized humerus design or the use of tuberosity augments may be useful to reduce the rate of implant instability due to the glenohumeral compressive forces provided by increased deltoid wrapping effect.

An APC technique is a technique in which a humeral stem is cemented in a matched proximal humerus allograft, and this construct is cemented into the native residual humerus [15–17]. This technique can be done with a step cut or with a simple cut, and we favor a plate fixation to add for stability and to improve bone integration. The decision to replicate the humeral length is based on the extent of humeral loss and also on the type of glenoid revision being performed. In most cases, a reverse glenoid configuration will be used, and depending on the distalization and the size of the glenosphere, one must fine-tune the predicted bone loss planned on the preoperative study. Typically, we will obtain marked bilateral radiographs, and we will measure the amount of bone loss and the level of healthy bone to plan the humeral cut. After performing the host humeral bone and performed the glenoid revision we perform a "shuck test" in which we pull downward from the elbow and gauge the amount of residual bone defect. Ideally, we will have information regarding the diameter of the diaphyseal humerus to match the native humeral width as much as possible. The humeral cut is a simple but essential step. It is important to prevent gapping when fixing the APC to increase host-allograft contact. All efforts are made in order to make the cuts of the residual humerus and APC as parallel as possible to increase the rate of bony union. We trial the APC-trial composite before cementing, and after we are satisfied with the length and stability, we plan plate fixation by predrilling the distal screws avoiding the trial stem.

The host humeral canal is then cemented, and the APC is introduced, and plate fixation is performed. Residual instability is managed by increasing humeral polyethylene liners and augmented humeral trays (Fig. 8.5). We favor using

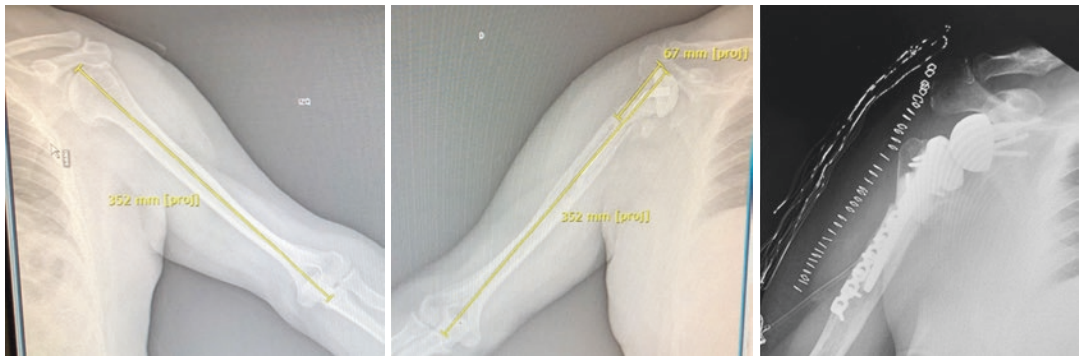

Fig. 8.5 Allograft-prosthesis composite (APC) technique. Prior to perform the APC technique, we obtain full-length bilateral radiographs to measure the proximal humerus defect. At the far right, a postoperative radiograph of a reversed shoulder arthroplasty (RSA)-APC cemented distally and fixed with a plate with screws that avoid the stem distally and proximally

allografts with remnants of the cuff, and we will try to suture the remaining cuff of the patient to the allograft to improve stability and function.

Sanchez-Sotelo et al. reported on the use of APC reconstruction in eight primary and 18 revision TSAs with a compression plate fixation of the APC for bone loss after trauma, tumor resection failed hemiarthroplasty, revision of failed anatomical total shoulder arthroplasty, and failed reverse shoulder arthroplasty [17]. The main reason for revision arthroplasty was instability. At a mean of 4 years follow-up, there were no clinical differences between primary and revision cases. No patient required revision for nonunion at the host-allograft junction. The time to union was 7 months, and one patient required additional surgery for grafting. They reported cases of dislocation, deep infection, one graft fracture, and one periprosthetic fracture distal to the APC construct with an overall survival rate at 5 years of 96%.

Other authors have used a step cut and 1.7-mm cables to stabilize the proximal allograft to the native humerus. In a study reviewing 73 patients with an average bone loss measured on immediate postoperative radiographs of 55.0 mm (range, 20–211 mm), the authors observed union in the metaphysis in 39 of 73 patients (53%) and at the diaphysis in 61 of 73 patients (84%) [15]. Radiographic humeral loosening was observed in ten patients at final follow-up. The reoperation-free survival rate of all reconstructions was 88% (30 of 34) at 5 years, 78% (21 of 27) at 10 years, and 67% (8 of 12) beyond 10 years with revision for periprosthetic fracture being the most frequent cause.

Infection is concered with the use of bulky allografts, but in a series of 25 tumor patients, Meijer et al. showed good healing of the allograft union and only one case of infection which highlights that they can be used safely [18].

8.4 Revision for Infection

The rate of infection is variable, as multiple definitions for infection have been used across the literature, which makes a comparison between different results difficult [19]. Pottinger et al. detected as much as a 56% rate of infection in revision shoulder arthroplasty which is much higher than the 1% overall risk after TSA and 3% after reversed shoulder arthroplasty (RSA) [20]. These numbers may be affected by certain preoperative risks such as being a male or having failed prior surgery for trauma. Richards et al. estimated the risk of being a male and having the need to use a shoulder arthroplasty for trauma increased the risk by 2.6 and 3, respectively [21].

Slow-growing pathogens cause most cases of infected revision arthroplasty, most typically *Cutibacterium acnes* and *Staphylococcus epidermidis*, and it is typical that they cause mild symptoms (pain and stiff shoulder) with a discrete elevation of serological markers [C-reactive protein (CRP), erythrocyte sedimentation rate (ESR)] if any. A draining sinus is diagnostic of infection and should orient the presurgical study toward detection of other kinds of pathogens. Trying to detect the pathogen through aspiration can be performed, and different test can be made. A cell count <200 cells/μL with greater than 70% polymorphonuclear (PMN) cells has been suggested as an indication of late periprosthetic joint infection (PJI) [22]. The use of alpha-defensin in the aspirated liquid has been shown to have a sensitivity of 63% and specificity of 95% [23]. Cultivation of joint aspirate has been reported to have a sensitivity of 82% in the diagnosis of PJI of the shoulder. Obtaining an odd number of periprosthetic material (most usually, five) for biopsies during the surgery and cultivation is the gold standard for infection, with efforts to try to minimize cross-contamination. If there is a suspicion for infection by *C. acnes*, a long incubation time is recommended, at least 3 weeks, as many bacteria will appear only in the second week of incubation [20, 24].

When comparing the output of open biopsies and aspiration of synovial fluid, Dilisio et al. found that open biopsy was more reliable with a sensitivity, specificity, positive predictive value, and negative predictive value of 100% compared to aspiration which had values of 16.7% sensitivity, 100% specificity, and a positive predictive value of 100% [24].

The surgical treatment of infection varies upon presentation, but it is classified into acute

and late presentations, 1 month being set as the arbitrary and artificial cutoff. Treatment of acute infection includes an aggressive surgical debridement, copious irrigation, and exchange of the modular parts of the arthroplasty, if any, associated with empiric antibiotic therapy, until identification of the pathogen, is achieved. We favor using rifampicin as it is active against nonresistant bacteria from the biofilm, as shown by Zimmerli et al., associated with quinolones, or vancomycin, if resistance is a problem in the target population, until proper identification is performed, for 6 weeks postoperatively [25]. With such treatment, success is in the realm of 80%.

Late infection is treated by debridement of the soft tissue, resection arthroplasty, a permanent spacer, and one-stage or two-stage septic revision. The rate of success in the treatment of PJI is greater with two-stage revision, but some of the patients are old, and there is an interest in performing only one surgery (Table 8.2) [26–36].

After debridement, some authors have used a spacer to increase the local levels of antibiotics and to maintain the tension of the soft tissues. Some patients will be happy with space, while others will have pain from instability and continued glenoid erosion. Commercially available spacers can keep high levels of elution for a more extended time, but, in contrast, there is a limited choice of antibiotics to choose from.

Most typically a patient will undergo a two-stage revision strategy, with the benefit of higher rates of eradication due to two surgical debridements and hindered by the personal implications, cost, and complications of additional surgery. Most studies include the use of a spacer, 6 weeks of antibiotics, and a new operation a minimum of 2 weeks after ending the antibiotic treatment and normalization of the biomarkers. With this strategy, patients will improve their function modestly and will achieve eradication close to 100% (Table 8.2) [26–36].

One-stage revision achieves eradication for the infection close to 95% and has the advantage of avoiding on surgery but is generally reserved for patients in which the pathogen is known, there are adequate antibiotic regimes for its, and the patient is healthy enough to receive them. Klatte et al. reported the outcomes of 35 patients treated at a specialized center with a mean follow-up of 4.7 years. The technique used was an ample resection of infected tissues, irrigation with polyhexanide, and new draping before reimplantation and specific intravenous antibiotherapy for an average of 2 weeks postoperatively and reported a success rate of 90% [37].

Table 8.2 Comparative results of different surgical approach for periprosthetic joint infection

Authors	*N*	Follow-up (years)	Implant used	Success rate	Constant score
One-stage revision results					
Klatte et al. [26]	35	4.7	RSA, HA, Bip	94	43.3 (hemi), 56 (bipolar), 61 (RSA)
Grosso et al. [27]	17	3	RSA, TSA, HA	94.1	NA
Beekman et al. [28]	11	2	RSA	94	55.6
Ince et al. [29]	9	5.8	TSA, HA	100	NA
Cuff et al. [30]	7	3.6	TSA, HA	100	Same as two-stage
Coste et al. [31]	3	2.8	TSA, HA	100	38
Jacquot et al. [32]	5	3	RSA	73	51
Two-stage revision results					
Strickland et al. [33]	19	2.9	HA, TSA	63	NA
Romanoo et al. [34]	17	3.8	RSA, HA	100	38
Sabesan et al. [35]	17	3.8	RSA, TSA, HA	94	66.4 (Penn Score)
Jacquot et al. [32]	14	3	RSA	67	46
Ortmaier et al. [36]	12	6.1	RSA	75	42.6
Coste et al. [31]	10	2.8	TSA, HA	60	35
Cuff et al. [30]	10	3.6	HA	100	Same as single stage

N = number; RSA = reverse shoulder arthroplasty; HA = hemiarthroplasty; Bip = bipolar; TSA = total shoulder arthroplasty

Resection arthroplasty is a salvage procedure reserved for the medically unfit, for recalcitrant infections in a low-demand patient. The infection is usually controlled, and pain control is achieved 50% of the times. Functional results are compromised with less than 70° of forward flexion and are typically associated with bone loss and soft tissue deficiency that may cause residual anterosuperior migration and limit the functional results [38].

8.5 Conclusions

Revision shoulder arthroplasty is a challenging situation for both the patient and the surgeon. Adequate diagnosis as to the reason for failure is the first step for an adequate treatment strategy. Adequate imaging studies and investigation of infection are necessary. Bone loss, both at the humeral and glenoid side, complicates the procedure as complex additional surgical techniques for reconstruction may be needed. The extraction of a prior arthroplasty can be very difficult and may be another reason for bone loss at the time of the revision. Some of these procedures need bone grafting and may need two procedures. Failure of the rotator cuff is often present and precludes the use of a reverse shoulder design.

References

1. Wagner ER, Chang MJ, Welp KM, Solberg MJ, Hunt TJ, Woodmass JM, et al. The impact of the reverse prosthesis on revision shoulder arthroplasty: analysis of a high-volume shoulder practice. J Shoulder Elbow Surg. 2019;28(2):e49–56.
2. Walch G, Bacle G, Ladermann A, Nove-Josserand L, Smithers CJ. Do the indications, results, and complications of reverse shoulder arthroplasty change with surgeon's experience? J Shoulder Elbow Surg. 2012;21(11):1470–7.
3. Barco R, Savvidou OD, Sperling JW, Sanchez-Sotelo J, Cofield RH. Complications in reverse shoulder arthroplasty. EFORT Open Rev. 2016;1(3):72–80.
4. Foruria AM, Oh LS, Sperling JW, Cofield RH. Anteromedial approach for shoulder arthroplasty: current indications, complications, and results. J Shoulder Elbow Surg. 2010;19(5):734–8.
5. Antuna SA, Sperling JW, Cofield RH, Rowland CM. Glenoid revision surgery after total shoulder arthroplasty. J Shoulder Elbow Surg. 2001;10(3):217–24.
6. Wagner E, Houdek MT, Griffith T, Elhassan BT, Sanchez-Sotelo J, Sperling JW, et al. Glenoid bone-grafting in revision to a reverse total shoulder arthroplasty. J Bone Joint Surg Am. 2015;97(20):1653–60.
7. Norris TR. Glenoid bone loss in reverse shoulder arthroplasty treated with bone graft techniques. Am J Orthop. 2018;47:3.
8. Cil A, Veillette CJ, Sanchez-Sotelo J, Sperling JW, Schleck C, Cofield RH. Revision of the humeral component for aseptic loosening in arthroplasty of the shoulder. J Bone Joint Surg. 2009;91(1):75–81.
9. Sahota S, Sperling JW, Cofield RH. Humeral windows and longitudinal splits for component removal in revision shoulder arthroplasty. J Shoulder Elbow Surg. 2014;23(10):1485–91.
10. Sperling JW, Cofield RH. Humeral windows in revision shoulder arthroplasty. J Shoulder Elbow Surg. 2005;14(3):258–63.
11. Wagner ER, Houdek MT, Hernandez NM, Cofield RH, Sanchez-Sotelo J, Sperling JW. Cement-within-cement technique in revision reverse shoulder arthroplasty. J Shoulder Elbow Surg. 2017;26(8):1448–53.
12. Budge MD, Moravek JE, Zimel MN, Nolan EM, Wiater JM. Reverse total shoulder arthroplasty for the management of failed shoulder arthroplasty with proximal humeral bone loss: is allograft augmentation necessary? J Shoulder Elbow Surg. 2013;22(6):739–44.
13. Stephens SP, Paisley KC, Giveans MR, Wirth MA. The effect of proximal humeral bone loss on revision reverse total shoulder arthroplasty. J Shoulder Elbow Surg. 2015;24(10):1519–26.
14. Abdeen A, Hoang BH, Athanasian EA, Morris CD, Boland PJ, Healey JH. Allograft-prosthesis composite reconstruction of the proximal part of the humerus: functional outcome and survivorship. J Bone Joint Surg Am. 2009;91(10):2406–15.
15. Cox JL, McLendon PB, Christmas KN, Simon P, Mighell MA, Frankle MA. Clinical outcomes following reverse shoulder arthroplasty-allograft composite for revision of failed arthroplasty associated with proximal humeral bone deficiency: 2- to 15-year follow-up. J Shoulder Elbow Surg. 2019;28(5):900–7.
16. McLendon PB, Cox JL, Frankle MA. Humeral bone loss in revision shoulder arthroplasty. Am J Orthop. 2018;47:2.
17. Sanchez-Sotelo J, Wagner ER, Sim FH, Houdek MT. Allograft-prosthetic composite reconstruction for massive proximal humeral bone loss in reverse shoulder arthroplasty. J Bone Joint Surg Am. 2017;99(24):2069–76.
18. Meijer ST, Paulino Pereira NR, Nota S, Ferrone ML, Schwab JH, Lozano Calderon SA. Factors associated with infection after reconstructive shoulder surgery

for proximal humerus tumors. J Shoulder Elbow Surg. 2017;26(6):931–8.
19. Parvizi J, Jacovides C, Zmistowski B, Jung KA. Definition of periprosthetic joint infection: is there a consensus? Clin Orthop Relat Res. 2011;469(11):3022–30.
20. Pottinger P, Butler-Wu S, Neradilek MB, Merritt A, Bertelsen A, Jette JL, et al. Prognostic factors for bacterial cultures positive for Propionibacterium acnes and other organisms in a large series of revision shoulder arthroplasties performed for stiffness, pain, or loosening. J Bone Joint Surg Am. 2012;94(22):2075–83.
21. Richards J, Inacio MC, Beckett M, Navarro RA, Singh A, Dillon MT, et al. Patient and procedure-specific risk factors for deep infection after primary shoulder arthroplasty. Clin Orthop Relat Res. 2014;472(9):2809–15.
22. Moroder P, Trampuz A, Scheibel M. Propionibacterium: we found it, now we have to deal with it: commentary on an article by Jason E. Hsu, MD, et al.: "Single-stage revision is effective for failed shoulder arthroplasty with positive cultures for propionibacterium". J Bone Joint Surg Am. 2016;98(24):e112.
23. Frangiamore SJ, Saleh A, Grosso MJ, Kovac MF, Higuera CA, Iannotti JP, et al. alpha-Defensin as a predictor of periprosthetic shoulder infection. J Shoulder Elbow Surg. 2015;24(7):1021–7.
24. Dilisio MF, Miller LR, Warner JJ, Higgins LD. Arthroscopic tissue culture for the evaluation of periprosthetic shoulder infection. J Bone Joint Surg Am. 2014;96(23):1952–8.
25. Zimmerli W, Sendi P. Role of rifampin against staphylococcal biofilm infections in vitro, in animal models, and in orthopedic-device-related infections. Antimicrob Agents Chemother. 2019;63(2):e01746-18.
26. Klatte TO, Sabihi R, Guenther D, Kamath AF, Rueger JM, Gehrke T, et al. High rates of occult infection after shoulder fracture fixation: considerations for conversion shoulder arthroplasty. HSS J. 2015;11(3):198–203.
27. Grosso MJ, Sabesan VJ, Ho JC, Ricchetti ET, Iannotti JP. Reinfection rates after 1-stage revision shoulder arthroplasty for patients with unexpected positive intraoperative cultures. J Shoulder Elbow Surg. 2012;21(6):754–8.
28. Beekman PD, Katusic D, Berghs BM, Karelse A, De Wilde L. One-stage revision for patients with a chronically infected reverse total shoulder replacement. J Bone Joint Surg. 2010;92(6):817–22.
29. Ince A, Seemann K, Frommelt L, Katzer A, Loehr JF. One-stage exchange shoulder arthroplasty for peri-prosthetic infection. J Bone Joint Surg. 2005;87(6):814–8.
30. Cuff DJ, Virani NA, Levy J, Frankle MA, Derasari A, Hines B, et al. The treatment of deep shoulder infection and glenohumeral instability with debridement, reverse shoulder arthroplasty and postoperative antibiotics. J Bone Joint Surg. 2008;90(3):336–42.
31. Coste JS, Reig S, Trojani C, Berg M, Walch G, Boileau P. The management of infection in arthroplasty of the shoulder. J Bone Joint Surg. 2004;86(1):65–9.
32. Jacquot A, Sirveaux F, Roche O, Favard L, Clavert P, Mole D. Surgical management of the infected reversed shoulder arthroplasty: a French multicenter study of reoperation in 32 patients. J Shoulder Elbow Surg. 2015;24(11):1713–22.
33. Strickland JP, Sperling JW, Cofield RH. The results of two-stage re-implantation for infected shoulder replacement. J Bone Joint Surg. 2008;90(4):460–5.
34. Romano CL, Borens O, Monti L, Meani E, Stuyck J. What treatment for periprosthetic shoulder infection? Results from a multicentre retrospective series. Int Orthop. 2012;36(5):1011–7.
35. Sabesan VJ, Ho JC, Kovacevic D, Iannotti JP. Two-stage reimplantation for treating prosthetic shoulder infections. Clin Orthop Relat Res. 2011;469(9):2538–43.
36. Ortmaier R, Resch H, Hitzl W, Mayer M, Stundner O, Tauber M. Treatment strategies for infection after reverse shoulder arthroplasty. Eur J Orthop Surg Traumatol Orthop Traumatol. 2014;24(5):723–31.
37. Klatte TO, Schneider MM, Citak M, Oloughlin P, Gebauer M, Rueger M, et al. Infection rates in patients undergoing primary knee arthroplasty with pre-existing orthopaedic fixation-devices. Knee. 2013;20(3):177–80.
38. Sperling JW, Kozak TK, Hanssen AD, Cofield RH. Infection after shoulder arthroplasty. Clin Orthop Relat Res. 2001;382:206–16.

9 Revision Total Shoulder Arthroplasty: Complications and Results

Alfonso Vaquero-Picado, Samuel Antuña, and Raul Barco

9.1 Introduction

Arthroplasty implantation has become a common procedure in shoulder surgery [1]. Rate of operations duplicated in USA from 2005 to 2013 (from 6.1 per 100,000 to 13.4 per 100,000) [2]. In the Finnish registry, it has multiplied up to five times in the last two decades [3] and continues to increase.

In the last decades, designs have improved, and trends in implantation have shifted from a high number of hemiarthroplasties (HA) to a higher number of total shoulder arthroplasties (TSA) and, especially in the last 15 years, a dramatic increase of reverse shoulder arthroplasties (RSA) [2, 4].

With the increase in the total number of arthroplasties, complications have risen as well. Zumstein defined a complication as any intraoperative or postoperative event that was likely to have a negative influence on the outcome [5]. Expanding indications of shoulder arthroplasty will determine an increased number of complications intra- and postoperatively, even higher in the case of revision [5, 6].

Complications leading to revision are multiple, and many times, they are associated [7]. Revision surgery is a complex procedure, and time should be taken to assess every single problem and its management [5, 7]. Facing this, the surgeon should ask himself the following: what complications are present, surgical strategy if it is necessary a staged procedure (i.e. can the implant can be kept or not?) and what are the expectable results [8].

9.2 History and Epidemiology

Shoulder prosthesis is a reliable procedure to manage multiple shoulder conditions. Indications have varied along time with a dramatic increase of reverse shoulder prosthesis in the last decade [5].

Actual TSA models are the evolution of the initial total shoulder prosthesis designed by Neer [9]. Initially composed of a single stem, glenoid components were added in the second version (Neer II) of the prosthesis [10]. Although indications were broad in the beginning, TSA is restricted at this moment to the treatment of osteoarthritis without severe distortion of the anatomy and good rotator cuff function. Its implantation has increased notably from the 1980s, but the apparition of RSA has slowed down its expansion. In the case of hemiarthroplasty, its use at this moment is reserved for irreparable proximal humerus fractures in a patient without osteoarthritis and a healthy rotator cuff.

A. Vaquero-Picado (✉) · S. Antuña · R. Barco
Upper Limb Unit, Department of Orthopedics, Hospital Universitario La Paz, Madrid, Spain

E. C. Rodríguez-Merchán (ed.), *Revision Total Joint Arthroplasty*,
https://doi.org/10.1007/978-3-030-24773-7_9

Paul Grammont designed in the 1980s the first RSA to provide good functional results, based on medialization of the center of rotation to optimize deltoid function [11]. This revolutionary concept led to an improvement of shoulder function in comparison with previous designs while providing stability and pain relief. Initially, it was used for the treatment of rotator cuff arthropathy, but indications have expanded in the last decade to include proximal humeral fractures, primary osteoarthritis with severe distortion of the anatomy and most of the revision surgeries [5]. RSA implantation has increased dramatically in recent years and is the implant of choice in most of the revisions due to the compromised function of the rotator cuff [2, 3, 5].

In a study conducted by Zumstein et al. [5] the global rate of complications in RSA implantation was 24%, instability being the most prevalent (4.7%) followed by infection (4%). This study reviewed the published experience during the 2000s, reflecting high variability of implants, approaches and surgical techniques. Knowledge of the implant, changes in the design and improved surgical techniques have decreased the complication rate.

Revision of a TSA or HA to another TSA or hemiarthroplasty is very rare. Although its high rate of complications (20–31%) and additional revision surgery (about 15–26% of implant revision at 5 years of follow-up), almost all shoulder arthroplasties (excepting some cases of resurfacing) are reviewed to RSA today [4, 12–16]. Thus, in this chapter, we will focus on the main complications the surgeon should address in case of revision with this type of implant.

9.3 Causes of Revision

The general revision rate is about 5–10% [8, 17]. Revision surgery has an increased 30-day postoperative complication rate and wound infections in comparison with primary shoulder arthroplasties [18]. In registry studies, it has been observed that intraoperative complications are higher in revision surgery in comparison with primary procedures [19].

Some changes have occurred within the last two decades regarding the incidence of complications. In the early 2000s, prosthetic instability was reported as the leading cause of revision. In a review by Boileau, [7] an incidence of 38% of instability was reported, indeed a very high rate, compared with the 4.7% reported by Zumstein et al. in 2010 [5]. Its incidence continues to decrease with new implants with a modified design [17, 20, 21].

After instability, infection used to be the second most frequent reason for revision surgery. However, nowadays, it is considered the most frequent complication leading to revision [17]. It affects about 4–5% of cases of RSA.

Mechanical complications are a common cause of revision as well. This category includes glenoid or humeral loosening and problems with the hardware, like glenoid disassembly. Scapular notch and acromial fractures are included in this category. Stiffness or periprosthetic fractures are less common complications that may lead to revision RSA. Periprosthetic fracture has the highest rate of intraoperative complications among revision causes [19].

Obesity and male gender have a higher rate of revision [17, 22]. However, age cannot be considered as an isolated reason to discard revision surgery. In a recent report of revisions in people over 80 years old, the revision rate was 16% at 5-year follow-up [23]. As a rule, even if there are no complications, subjective results and function are worse after revision surgery in comparison with primary procedures [12, 14, 24].

9.3.1 Instability

Instability has been reported as the most common complication after primary RSA and the second in frequency in TSA [8]. Its incidence is still higher in revision RSA [20]. However, RSA has become the elective procedure to resolve instability in TSA and hemiarthroplasties [25]. In patients undergoing RSA for previous instability, the rate of postoperative instability and reoperation for instability is higher than in revision RSA for other causes [25].

A previous operation, performed with a deltopectoral approach (in contrast to the superolateral approach), humeral or glenoid bone loss and subscapularis deficiency are the most common risk factors for prosthesis instability. In addition to previous factors, component malposition (inadequate version or height), excessive medialization of the glenoid and a shortened humerus by bone loss should be looked for and addressed when facing revision of RSA for instability.

Abdelfattah et al. have proposed a classification of postoperative instability after RSA [26]. They differentiate three groups:

- Group I—Loss of compression: Due to those alterations that diminish the cooptation of the prosthesis. Includes undersized implants, loss of deltoid contour, humeral height loss, subscapularis deficiency, acromial/scapular fracture, and deltoid dysfunction.
- Group II—Loss of containment: Failure of glenosphere-humerus socket articulation, destabilizing the fulcrum required for arm elevation. Can be caused by mechanical failure or eccentric polyethylene wear.
- Group III—Impingement: When an obstacle limits the range of motion of the prosthesis and includes soft tissue or bony impingement, prosthetic malalignment or obesity.

9.3.1.1 Management

Early dislocation (<3 months after operation) managed initially by closed reduction is effective in about 60% of cases to address instability after RSA but is not always possible [8, 20]. After reduction, the shoulder should be immobilized in an abduction splint.

In the series published by Chalmers et al., the rate of early instability was 2.9% [27]. Of the 11 patients with dislocation, 9 could be managed by closed reduction and 2 needed open reduction. After that, five patients underwent revision to a thicker polyethylene, 82% of primary implant retaining rate. In two patients, instability persisted and needed revision to HA.

After 3 months, instability is mainly due to deltoid insufficiency. Humeral shortening and/or glenoid medialization are frequently present as well as other factors of Groups I and II. At this moment, instability almost always requires a surgical procedure.

Shortening can be addressed on the humeral or glenoid sides. On the humeral side, a thicker polyethylene or baseplate can resolve the problem. Stem exchange should be performed in case of inadequate height or version. If stem removal is needed, a lateralized stem is a good option to provide increased stability [8]. Bilateral radiographs of the humerus are recommended to detect any humeral shortening or bone loss [7].

On the glenoid side, lateralizing can be achieved by exchanging the glenosphere to a higher size or adding a supplement (osseous or metallic) to the baseplate.

Soft tissue procedures can augment implant modifications. The subscapularis tendon is rarely present and pliable, but if so, a repair should be tried. Immobilization in an abduction splint for 4–6 weeks can promote deltoid shortening, increasing coaptation force.

In the case of neurological disease affecting deltoid function, instability may persist. RSA explantation and revision to HA can be an option to keep some function and aesthetics [27].

In the series by Abdelfattah et al. [26], only 21 of 43 cases of revision RSA for instability remained stable after 2 years, which shows a poor outcome of revision surgery for instability even when a more stable implant (lateralized on glenoid side) was used for revision.

9.3.2 Infection

Infection is the second most frequent cause of prosthetic revision surgery. Having previous surgery is the main risk factor for infection in the shoulder [8], and the risk increases with the number of surgeries.

Clinical presentation is variable. It can have an acute course, usually with erythema, drainage or wound dehiscence. In the chronic setting, an infection has many presentations, but it must be always suspected in case of chronic pain and stiffness. Loosening, erythema, swelling, repetitive effusion and fistulization only add to the suspicion.

The most common pathogens are *Cutibacterium acnes*, *Staphylococcus epidermidis* and *Staphylococcus aureus*. Samples can be obtained by arthrocentesis or intraoperatively (at least five samples). It is important to culture samples for a prolonged time as *Cutibacterium acnes* growth may take up to 2–4 weeks) [28].

Infection is a catastrophic and challenging complication. Treatment depends on the patient's status, infection onset and microorganisms and should be approached in a multidisciplinary way. As a rule, all infections should be managed with surgery and prolonged antibiotherapy.

Regarding acute or delayed-onset acute hematogenous infections, irrigation plus debridement, and exchange of mobile pieces of the prosthesis can be an option [29, 30]. However, in a series published by Dennison et al. [30], from ten patients with acute shoulder prosthesis infections treated with irrigation and debridement, three underwent resection arthroplasty, and five of the remaining patients were treated with chronic antibiotic suppression. Only 20% of patients treated with irrigation and debridement for an acute prosthesis retained the implant and were free of disease after the treatment. Further investigations in this field should be performed, and it can be advisable to the patient undergoing a revision for infection of a revision prosthesis probably will have still worse results.

With a chronic infection onset, implant replacement or resection arthroplasty is the main option of treatment. Functional results after infection treatment are almost always worse than those of the previous prosthesis [8].

Resection arthroplasty should only be performed in case of resistant infection, fragile patients or failure after multiple surgical attempts. Functional results are unsatisfactory, so it reserved as a salvage procedure [7].

Implant replacement is considered for the treatment of chronic infections. It provides the best and more predictable results for the treatment of prosthetic infection. However, it is technically challenging, and many complications can occur during the procedure [7, 8].

Diagnosis of chronic shoulder prosthesis infection is difficult, and there is a lack of strong evidence supporting diagnostic strategies. Most patients will have pain and stiffness. All patients should have full-length humerus radiographs and laboratory exams including blood count, erythrocyte sedimentation rate (ECR) and C-reactive protein (CRP) [31]. For *C. acnes* infection, only deep samples of suspected infected tissue should be used. *C. acnes* are a saprophyte of the shoulder, and it is present in up to 18.8% of deep layers in samples taken during a first procedure. Several criteria, like Lutz's et al.'s [32] or Asserays et al.'s [33] (Tables 9.1 and 9.2), have been developed to assist in the difficult diagnosis of an infection by *C. acnes* giving the chance of having a positive culture or a true infection.

Treatment strategies in chronic infection vary from a scheduled implant replacement (one, two or three stage) [34] to resection arthroplasty. In a patient with good functional status, scheduled replacement is the best choice. In most of the published series, there is no difference between one-stage or sequential replacement in terms of eradication of infection.

Table 9.1 Lutz et al. classification [32]

Group	Type of infection	Clinical signs of infection	Number of positive samples
I	Certain	Present	≥ 2
II	Probable	Present	1
III	Possible	Absent	≥ 1

Table 9.2 Asseray et al. classification [33]

Number of positive samples	Number of associated signs	Including
≥2	+1	• ≥ 2 local surgeries • Presence of orthopedic implant • Local signs of infection • Loosening
1	+3	• ≥ 2 local surgeries • Presence of orthopedic implant • Local signs of infection • Inflammatory syndrome • Loosening

In a series published by Sevelda et al. [35], 93% of 14 cases were free of infection at 5-years follow-up. The authors performed a preoperative study obtaining cultures of articular fluid or synovium. If cultures were negative, a one-stage procedure was performed. In a recent systematic review, a one-stage procedure was reported as the best procedure (in comparison with staged revision, permanent cement spacers and resection arthroplasty) in terms of function [36, 37].

A staged procedure usually includes two phases: (1) explantation, debridement, cement spacer implantation and directed antibiotherapy and (2) reimplantation once biological markers have returned to normal values with absence of clinical signs of infection. With this protocol, Assenmacher et al. [38] reported an 85% of survival free of infection after 5-years follow-up, which is in line with the literature [39].

Tseng et al. [34] reported 100% of survival free of infection in 28 cases at 32 months follow-up after a three-staged procedure. This protocol consists of (1) explantation, debridement, implantation of cement spacer and parenteral antibiotics, (2) open biopsy and debridement and (3) reimplantation, if cultures were negative.

However, in a series by Stone et al. [40], they reported no differences in infection eradication after the one- or two-stage procedure. These authors concluded that revision for infection has an increased risk of infection compared with primary procedures. As a general rule, a staged procedure is indicated in case of history of previous surgery or if the bacteria is unknown or multiresistant [8].

9.3.3 Implant Loosening and Bone Loss

9.3.3.1 Humeral Side

Initially, the glenoid side was thought to be more prone to failure after RSA but the constrained nature of this design produces increased stress and forces on the humeral side [8].

Humeral bone loss is frequent in posttraumatic and tumor surgery or in cases of proximal bone resorption. In this context, the stem is only stabilized distally in the humeral diaphysis. Forces are concentrated at this point, especially with rotational movements. Polyethylene and metal debris may also contribute to loosening, especially in case of scapular notching [8].

Contained defects can be managed using morcellized bone graft or cement. Stephens reported good results with the use of cemented with or without bone grafting in case of proximal humeral defects of less than 5 cm [41].

Uncontained defects or those in which humeral resection compromises deltoid function can be managed with an allograft prosthetic composite (APC) or a megaprosthesis [8]. APC is a good option in massive defects with a reoperation-free survival rate varying from 88% to 96% at 5 years-follow-up [42, 43].

Another cause of humeral defects is intraoperative fractures. Previous prosthesis instability, HA revision or being a female are risk factors for these fractures. However, Wagner et al. demonstrated that if the fracture is properly addressed final outcomes are not significantly affected [4].

9.3.3.2 Glenoid Side

As a rule, aseptic glenoid loosening is rare. In these cases, infection should always be suspected [44]. Aseptic loosening is almost always due to a technical error. A glenoid implant placed high or with superior inclination is associated with increased rates of notching. Severe cases of notching may increase the likelihood of developing aseptic glenoid loosening in RSA [8].

Cavitary glenoid defects can be managed with allograft impaction or structural iliac crest autograft. Both are useful, but in these cases, allograft works well and allows avoiding the morbidity associated with iliac crest harvest [45, 46]. In uncontained and complex glenoid defect, an autograft is preferable because of biological properties for incorporation. In primary cases, the resected humeral head can be utilized, but in revisions, the humeral head is not present, and iliac crest or allograft must be used [47, 48]. There are multiple ways to harvest the bone, and it can be adapted to the defect once addressed. One way is to harvest it as a wedge and fix it directly on the remnant bone of the glenoid. Norris et al. proposed a technique using iliac

crest in which the glenoid implant was directly prepared in the crest with the help of prosthesis reamers and instrumentation. Once the metaglene is implanted on the iliac crest, it is harvested and fixed with screws or a long-peg baseplate to the original glenoid [49].

Boileau [7] proposed an algorithm to treat glenoid bone loss in one or two stages. One-stage reimplantation can be afforded if the following conditions are present: (1) enough graft stability after impaction, (2) central peg or screw has, at least, 5 mm implanted in the native scapular bone and (3) additional fixation to the scapula can be obtained with screws. If these conditions are not present or it is advisable to have too much tension after reimplantation, it is preferable not to reimplant and let the graft consolidate properly. After 6 months, reimplantation is performed.

In case of massive bone loss, hemiarthroplasty as a salvage procedure is an option [50].

9.4 Conclusions

Reverse shoulder arthroplasty has become a common procedure to address multiple shoulder surgeries. Improvements in prosthetic designs and surgical technique have dramatically decreased complications in the last decade. However, the global rate of complications remains high. Most of complications leading to revision surgery, with prosthetic exchange, are addressed with an RSA. Instability incidence has dramatically decreased with new prosthetic designs. Closed reduction can be an option for instability in <3 months after primary surgery. However, the revision rate in this case is still high. In the chronic setting, it is better managed with implant exchange. In case of severe and recurrent instability, deltoid function should be carefully examined and HA can be used as a salvage procedure. Infection is a very severe complication. Lavage and debridement in acute infections has a low rate of success (about 20%). If it fails, or in the chronic setting, implant exchange is used. Several protocols have been proposed, but there is a lack of strong evidence. The one-stage procedure seems to provide better function in comparison with sequential treatment. However, multiresistant or unknown bacteria before revision surgery are better managed with staged procedures. Bone loss deficiency can be present on either the humeral or glenoid side. On the humeral side, impacted bone graft or cement is useful in contained defects. In uncontained defects compromising implant stability, megaprosthesis or a allograft prosthetic composite is used. On the glenoid side, contained defects can be addressed with an impacted graft. Complex defects can be managed with a structural graft. In these cases, implantation of a definitive baseplate should be only performed if the attachment to the scapular remnant is stable.

References

1. Kim SH, Wise BL, Zhang Y, Szabo RM. Increasing incidence of shoulder arthroplasty in the United States. J Bone Joint Surg Am. 2011;93:2249–54.
2. Dillon MT, Chan PH, Inacio MCS, Singh A, Yian EH, Navarro RA. Yearly trends in elective shoulder arthroplasty, 2005-2013. Arthritis Care Res. 2017;69:1574–81.
3. Harjula JNE, Paloneva J, Haapakoski J, Kukkonen J, Äärimaa V, Finnish Shoulder Arthroplasty Registry Group. Increasing incidence of primary shoulder arthroplasty in Finland—a nationwide registry study. BMC Musculoskelet Disord. 2018;19:245.
4. Wagner ER, Chang MJ, Welp KM, Solberg MJ, Hunt TJ, Woodmass JM, et al. The impact of the reverse prosthesis on revision shoulder arthroplasty: analysis of a high-volume shoulder practice. J Shoulder Elb Surg. 2019;28:e49–56.
5. Zumstein MA, Pinedo M, Old J, Boileau P. Problems, complications, reoperations, and revisions in reverse total shoulder arthroplasty: a systematic review. J Shoulder Elb Surg. 2011;20:146–57.
6. Barco R, Savvidou OD, Sperling JW, Sanchez-Sotelo J, Cofield RH. Complications in reverse shoulder arthroplasty. EFORT Open Rev. 2016;1:72–80.
7. Boileau P, Melis B, Duperron D, Moineau G, Rumian AP, Han Y. Revision surgery of reverse shoulder arthroplasty. J Shoulder Elb Surg. 2013;22:1359–70.
8. Boileau P. Complications and revision of reverse total shoulder arthroplasty. Orthop Traumatol Surg Res OTSR. 2016;102:S33–43.
9. Neer CS. Articular replacement for the humeral head. J Bone Joint Surg Am. 1955;37-A:215–28.
10. Neer CS, Watson KC, Stanton FJ. Recent experience in total shoulder replacement. J Bone Joint Surg Am. 1982;64:319–37.

11. Grammont P, Trouillloud P, Laffay J, Deries X. Étude et realisation d'une nouvelle prothèse d'épaule. Rhumatologie. 1987;39:409–18.
12. Sheth MM, Sholder D, Getz CL, Williams GR, Namdari S. Revision of failed hemiarthroplasty and anatomic total shoulder arthroplasty to reverse total shoulder arthroplasty. J Shoulder Elb Surg. 2019;28:1074–81.
13. Wagner ER, Hevesi M, Houdek MT, Cofield RH, Sperling JW, Sanchez-Sotelo J. Can a reverse shoulder arthroplasty be used to revise a failed primary reverse shoulder arthroplasty?: revision reverse shoulder arthroplasty for failed reverse prosthesis. Bone Joint J. 2018;100-B:1493–8.
14. Shields E, Wiater JM. Patient outcomes after revision of anatomic total shoulder arthroplasty to reverse shoulder arthroplasty for rotator cuff failure or component loosening: a matched cohort study. J Am Acad Orthop Surg. 2019;27:e193–8.
15. Petkovic D, Kovacevic D, Levine WN, Jobin CM. Management of the failed arthroplasty for proximal humerus fracture. J Am Acad Orthop Surg. 2019;27:39–49.
16. Stephens BC, Simon P, Clark RE, Christmas KN, Stone GP, Lorenzetti AJ, et al. Revision for a failed reverse: a 12-year review of a lateralized implant. J Shoulder Elb Surg. 2016;25:e115–24.
17. Lehtimäki K, Rasmussen JV, Mokka J, Salomonsson B, Hole R, Jensen SL, et al. Risk and risk factors for revision after primary reverse shoulder arthroplasty for cuff tear arthropathy and osteoarthritis: a Nordic Arthroplasty Register Association study. J Shoulder Elb Surg. 2018;27:1596–601.
18. Boddapati V, Fu MC, Schairer WW, Gulotta LV, Dines DM, Dines JS. Revision total shoulder arthroplasty is associated with increased thirty-day postoperative complications and wound infections relative to primary total shoulder arthroplasty. HSS J. 2018;14:23–8.
19. Ingoe HM, Holland P, Cowling P, Kottam L, Baker PN, Rangan A. Intraoperative complications during revision shoulder arthroplasty: a study using the National Joint Registry dataset. Shoulder Elb. 2017;9:92–9.
20. Teusink MJ, Pappou IP, Schwartz DG, Cottrell BJ, Frankle MA. Results of closed management of acute dislocation after reverse shoulder arthroplasty. J Shoulder Elb Surg. 2015;24:621–7.
21. Kang JR, Dubiel MJ, Cofield RH, Steinmann SP, Elhassan BT, Morrey ME, et al. Primary reverse shoulder arthroplasty using contemporary implants is associated with very low reoperation rates. J Shoulder Elb Surg. 2019;28(6S):S175–80. https://doi.org/10.1016/j.jse.2019.01.026. pii: S1058-2746(19)30077-1
22. Werner BC, Burrus MT, Begho I, Gwathmey FW, Brockmeier SF. Early revision within 1 year after shoulder arthroplasty: patient factors and etiology. J Shoulder Elb Surg. 2015;24:e323–30.
23. Alentorn-Geli E, Clark NJ, Assenmacher AT, Samuelsen BT, Sánchez-Sotelo J, Cofield RH, et al. What are the complications, survival, and outcomes after revision to reverse shoulder arthroplasty in patients older than 80 years? Clin Orthop Relat Res. 2017;475:2744–51.
24. Randelli P, Randelli F, Compagnoni R, Cabitza P, Ragone V, Pulici L, et al. Revision reverse shoulder arthroplasty in failed shoulder arthroplasties for rotator cuff deficiency. Joints. 2015;3:31–7.
25. Hernandez NM, Chalmers BP, Wagner ER, Sperling JW, Cofield RH, Sanchez-Sotelo J. Revision to reverse total shoulder arthroplasty restores stability for patients with unstable shoulder prostheses. Clin Orthop Relat Res. 2017;475:2716–22.
26. Abdelfattah A, Otto RJ, Simon P, Christmas KN, Tanner G, LaMartina J, et al. Classification of instability after reverse shoulder arthroplasty guides surgical management and outcomes. J Shoulder Elb Surg. 2018;27:e107–18.
27. Chalmers PN, Rahman Z, Romeo AA, Nicholson GP. Early dislocation after reverse total shoulder arthroplasty. J Shoulder Elb Surg. 2014;23:737–44.
28. Pottinger P, Butler-Wu S, Neradilek MB, Merritt A, Bertelsen A, Jette JL, et al. Prognostic factors for bacterial cultures positive for Propionibacterium acnes and other organisms in a large series of revision shoulder arthroplasties performed for stiffness, pain, or loosening. J Bone Joint Surg Am. 2012;94:2075–83.
29. Favard L. Revision of total shoulder arthroplasty. Orthop Traumatol Surg Res. 2013;99:S12–21.
30. Dennison T, Alentorn-Geli E, Assenmacher AT, Sperling JW, Sánchez-Sotelo J, Cofield RH. Management of acute or late hematogenous infection after shoulder arthroplasty with irrigation, débridement, and component retention. J Shoulder Elb Surg. 2017;26:73–8.
31. Marcheggiani Muccioli GM, Guerra E, Roberti di Sarsina T, Alesi D, Fratini S, Cammisa E, et al. Diagnosis and treatment of infected shoulder arthroplasty: current concepts review. Joints. 2018;6:173–6.
32. Lutz M-F, Berthelot P, Fresard A, Cazorla C, Carricajo A, Vautrin A-C, et al. Arthroplastic and osteosynthetic infections due to Propionibacterium acnes: a retrospective study of 52 cases, 1995-2002. Eur J Clin Microbiol Infect Dis. 2005;24:739–44.
33. Asseray N, Papin C, Touchais S, Bemer P, Lambert C, Boutoille D, et al. Improving diagnostic criteria for Propionibacterium acnes osteomyelitis: a retrospective analysis. Scand J Infect Dis. 2010;42:421–5.
34. Tseng W-J, Lansdown DA, Grace T, Zhang AL, Feeley BT, Hung L-W, et al. Outcomes of revision arthroplasty for shoulder periprosthetic joint infection: a three-stage revision protocol. J Shoulder Elb Surg. 2019;28:268–75.
35. Sevelda F, Fink B. One-stage exchange of septic shoulder arthroplasty following a standardized treatment algorithm. J Shoulder Elb Surg. 2018;27:2175–82.
36. Mercurio M, Castioni D, Iannò B, Gasparini G, Galasso O. Outcomes of revision surgery after periprosthetic shoulder infection: a systematic review. J Shoulder Elb Surg. 2019;28:1193–203.

37. Kunutsor SK, Wylde V, Beswick AD, Whitehouse MR, Blom AW. One- and two-stage surgical revision of infected shoulder prostheses following arthroplasty surgery: a systematic review and meta-analysis. Sci Rep. 2019;9:232.
38. Assenmacher AT, Alentorn-Geli E, Dennison T, Baghdadi YMK, Cofield RH, Sánchez-Sotelo J, et al. Two-stage reimplantation for the treatment of deep infection after shoulder arthroplasty. J Shoulder Elb Surg. 2017;26:1978–83.
39. Buchalter DB, Mahure SA, Mollon B, Yu S, Kwon YW, Zuckerman JD. Two-stage revision for infected shoulder arthroplasty. J Shoulder Elb Surg. 2017;26:939–47.
40. Stone GP, Clark RE, O'Brien KC, Vaccaro L, Simon P, Lorenzetti AJ, et al. Surgical management of periprosthetic shoulder infections. J Shoulder Elb Surg. 2017;26:1222–9.
41. Stephens SP, Paisley KC, Giveans MR, Wirth MA. The effect of proximal humeral bone loss on revision reverse total shoulder arthroplasty. J Shoulder Elb Surg. 2015;24:1519–26.
42. Cox JL, McLendon PB, Christmas KN, Simon P, Mighell MA, Frankle MA. Clinical outcomes following reverse shoulder arthroplasty-allograft composite for revision of failed arthroplasty associated with proximal humeral bone deficiency: 2- to 15-year follow-up. J Shoulder Elb Surg. 2019;28:900–7.
43. Sanchez-Sotelo J, Wagner ER, Sim FH, Houdek MT. Allograft-prosthetic composite reconstruction for massive proximal humeral bone loss in reverse shoulder arthroplasty. J Bone Joint Surg Am. 2017;99:2069–76.
44. Lucas RM, Hsu JE, Whitney IJ, Wasserburger J, Matsen FA. Loose glenoid components in revision shoulder arthroplasty: is there an association with positive cultures? J Shoulder Elb Surg. 2016;25:1371–5.
45. Ozgur SE, Sadeghpour R, Norris TR. Revision shoulder arthroplasty with a reverse shoulder prosthesis: use of structural allograft for glenoid bone loss. Orthopade. 2017;46:1055–62.
46. Wagner E, Houdek MT, Griffith T, Elhassan BT, Sanchez-Sotelo J, Sperling JW, et al. Glenoid bone-grafting in revision to a reverse total shoulder arthroplasty. J Bone Joint Surg Am. 2015;97:1653–60.
47. Mahylis JM, Puzzitiello RN, Ho JC, Amini MH, Iannotti JP, Ricchetti ET. Comparison of radiographic and clinical outcomes of revision reverse total shoulder arthroplasty with structural versus nonstructural bone graft. J Shoulder Elb Surg. 2019;28:e1–9.
48. Phipatanakul WP, Norris TR. Treatment of glenoid loosening and bone loss due to osteolysis with glenoid bone grafting. J Shoulder Elb Surg. 2006;15:84–7.
49. Norris TR. Glenoid bone loss in reverse shoulder arthroplasty treated with bone graft techniques. Am J Orthop (Belle Mead NJ). 2018;47(3) https://doi.org/10.12788/ajo.2018.0016.
50. Glanzmann MC, Kolling C, Schwyzer H-K, Audigé L. Conversion to hemiarthroplasty as a salvage procedure for failed reverse shoulder arthroplasty. J Shoulder Elb Surg. 2016;25:1795–802.

Revision Total Elbow Arthroplasty: Epidemiology and Causes

10

Alfonso Vaquero-Picado, Raul Barco, and Samuel Antuña

10.1 Introduction

The era of modern total elbow arthroplasty (TEA) was probably initiated in 1970s with the introduction of the Coonrad prosthesis [1]. Before this implant, all TEA models were primitive with inconsistent results. In the late 1970s, modifications introduced on design and surgical technique yielded better and more reliable results.

For many years, the great majority of elbow arthroplasties were implanted in rheumatoid elbows [2]. In this low-demand patient population, TEA was a successful intervention, improving significantly both the quality of life and pain with good long-term survivorship [3]. However, with the introduction of new drugs, rheumatoid patients are increasingly treated nonsurgically, and there has been a shift of indications for TEA to acute and chronic traumatic conditions. As trauma sequela after elbow fractures is a quite prevalent condition, the total number of TEA has lately increased. Elbow arthroplasty after trauma is performed in high demand patients and this will probably increase the revision rate of TEA in the future.

10.2 Modes of Failure

According to Morrey and Bryan [4], complications after TEA can be classified into three categories. One group includes complications that need revision surgery such as infection, aseptic loosening, some fractures, or mechanical component failure and instability. The second group includes complications that require additional surgery but not implant revision, such as ulnar nerve entrapment, stiffness or triceps insufficiency. In the third group these authors include complications that increase morbidity like wound infection or nerve paralysis/paresthesia.

This classification has some interest for epidemiological and academic purposes but is not really very useful for clinical use. It is, obviously, not the same to perform a revision of both components or perform an ulnar nerve transposition. In this chapter, we will mainly focus on revision surgery that requires component removal or exchange.

Wear of the polyethylene bushings after linked elbow arthroplasty is related to the development of aseptic loosening. Godberg et al. [5] reported wear in both ulnar and humeral bushing in more than 90% of cases. When the polyethylene is completely eroded, metal corrosion causes metal debris deposit on the bone-cement interface leading to aseptic loosening.

A. Vaquero-Picado (✉) · R. Barco · S. Antuña
Upper Limb Unit, Department of Orthopedics, Hospital Universitario La Paz, Madrid, Spain

E. C. Rodríguez-Merchán (ed.), *Revision Total Joint Arthroplasty*,
https://doi.org/10.1007/978-3-030-24773-7_10

10.3 General Epidemiology of Revision TEA

The complication rate after TEA, including revision of the components and other complications, has been reported to be around 24% [6]. In a systematic review conducted by Prkic et al., [2] the rate of revision after TEA was 13.5% with a mean follow-up of 81 months. Aseptic loosening was the most common cause of revision, representing 38% of all revisions. However, the rate of aseptic loosening varies between 6% and 20% of the total number of TEA. It is important to remark that TEA can show clinical signs of loosening with slight radiographic changes [6].

Infection after elbow replacement leading to revision surgery represents 19% of all revisions. A periprosthetic fracture requiring component exchange represents 12% of all revisions [2]. No differences in revision rate have been reported between males and females.

10.4 Type of Prosthesis

Rates of revision after linked or unlinked total elbow do not differ significantly in the literature [2]. Overall, revision rates vary between 10% to 15% at 10 years. Some authors have reported higher rates of revision after unlinked prosthesis, but there is still controversy on this topic [7]. Modes of failure are very different between both types of prosthesis [8].

Aseptic loosening is the main cause of revision elbow arthroplasty in the long term. The rate of revision may have decreased in the last decades after several modifications implemented on design and technique: better cementation, better polyethylene, etc. It has been also recognized the importance of restoring elbow kinematics by accurate alignment of the implants [9]. Improved fixation is directly related to a decrease incidence of delayed aseptic loosening [10].

Some mechanical failures are specific to linked implants, such as polyethylene wear, disassembly or material failure [2]. Aseptic loosening is relatively common and remains the main reason for TEA failure. However, mechanical loosening incidence has significantly decreased if we compare with the initial constrained models [2]. In these totally constrained, linked implants, the bone-cement interface submitted to a very high stress through a fixed flexion-extension hinge led to aseptic loosening of the humeral component.

Modern elbow linked designs are semiconstrained. They have a sloppy hinge linkage, which allows some varus-valgus movement during flexion-extension. This loose articulation dissipates some stress on the hinge, decreasing forces on the bone-cement interface and minimizing aseptic loosening rate in comparison with older models. However, the loose hinge places high stresses on the polyethylene bearing [6].

Aseptic loosening is largely the most common complication after unlinked prosthesis. This loosening is probably due to multidirectional forces acting during elbow flexion and extension. These forces get dissipated on the ulno-humeral union, leading to increased polyethylene wear. Polyethylene debris then accumulates on the bone-cement interface leading to osteolysis and loosening.

Elbow instability is almost an exclusive complication after unlinked prosthesis. Ligament repair and integrity is of paramount importance for maintaining stability after implantation of unlinked implants. Additionally, periprosthetic fractures are less common after unlinked models.

10.5 Primary Indications

The most frequent indication for primary TEA has traditionally been rheumatoid arthritis, followed by acute traumatic and posttraumatic conditions.

The best reported results on implant survivorship are those obtained in rheumatoid arthritis. In this group of patients, a survival rate of more than 90% at 10 years has been reported in the Mayo Clinic series [3]. Most rheumatoid patients undergoing elbow replacement have severe joint destruction and pain and are low demand, so they do not stress much the TEA.

However, new biologic drugs have changed the scenario in the rheumatoid elbow, and most of

these patients have their disease controlled and do not need an elbow replacement. Therefore, indications for TEA in inflammatory diseases are decreasing while patients are becoming more demanding. All these factors may have an impact in the future rate of revision TEA in rheumatoid patients [3].

In acute traumatic cases in elderly patients, severe osteopenia may affect primary stability of the prosthesis. The reported survivorship is up to 85–95% of cases in the context of acute trauma or posttraumatic sequelae [2, 8, 11]. However, the rate of complications not leading to revision is much higher in traumatic indications when compared with inflammatory arthritis [6].

Many patients undergoing elbow replacement after trauma may have a history of wound problems and previous surgeries. Under those circumstances, the surgeon should always discard the possibility of an infection before elbow replacement is considered [12, 13]. Many authors propose staging the definitive arthroplasty when an infection is suspected [13, 14]. In the first procedure, extensive debridement with removal of previous hardware is performed. Samples for microbiology and pathology studies are obtained. After the first procedure, once the skin is healed and the cultures have returned negative, the final arthroplasty is implanted.

The revision rate of TEA after primary osteoarthritis or hemophilic arthropathy is higher in comparison with other conditions [2]. In the Mayo Clinic series, 5 of 20 cases (25%) of TEA for primary osteoarthritis failed due to mechanical failures, including intraoperative fractures, fracture of the humeral component and loosening [15]. Revision rate after TEA for hemophilic arthropathy can be as high as 38% due mainly to mechanical failures [16, 17].

10.6 Short-Term and Long-Term Revisions

Infection can occur any time after TEA, but it is the main complication leading to revision within the first years after surgery. It can occur acutely, immediately after the index procedure or in a sub-acute manner, caused by a low-grade infection months or years after surgery [2, 13].

The rate of infection after TEA has been reported to be as high as 9% [6, 18]. This exceedingly high rate has been reduced in more recent series in which improvements in surgical technique, such as better tissue handling, skin protection or antibiotic-loaded bone cement, were implemented [6]. The rate of infection is not different based on the type of implant used [2, 13].

Most acute infections are caused by *S. aureus* and *S. epidermidis*. In the acute situation, it is usually more aggressive and it is considered a devastating complication. In this setting, extensive lavage and debridement with component retention has only yielded 50% success rate with better outcomes when the infection is caused by *S. aureus* compared with *S. epidermidis* [19]. Obviously, considering the high morbidity of well-fixed implants' removal, it is still reasonable to approach an acute infection with lavage and debridement [13, 20].

Chronic infections are usually due to low-grade infections (*S. epidermidis* or *P. acnes*). Component removal is normally required together with extensive debridement. Although one-stage revision surgery after infection might be an option, the two-stage procedure remains the standard procedure for chronic infections [1, 13]. When *S. epidermidis* is causing the infection, outcomes after two-stage procedures are poor [19].

In the long term, the most common reason for revision is aseptic loosening. Quite commonly, loosening is associated with periprosthetic fractures, and these are an important cause for revision at any time after TEA [2]. Periprosthetic fractures after elbow replacement may be very challenging and, quite commonly, require extensive reconstruction procedures with structural bone grafts.

10.7 Conclusions

Total elbow replacement has a higher revision rate than any other joint arthroplasty. Recent changes on implant design and improved surgical

technique have apparently decreased the risk of revision. These better outcomes may expand the current indications within the posttraumatic scenario. However, younger and active patients are more functionally demanding and this increases the predisposition to develop aseptic loosening that is still the main cause for revision. In visioning the future, it seems quite necessary to develop TEA with designs that improve the longevity by using better polyethylene and more physiological biomechanics.

References

1. Ramirez MA, Cheung EV, Murthi AM. Revision total elbow arthroplasty. J Am Acad Orthop Surg. 2017;25:e166–74.
2. Prkic A, Welsink C, The B, van der Bekerom MPJ, Eygendaal D. Why does total elbow arthroplasty fail today? A systematic review of recent literature. Arch Orthop Trauma Surg. 2017;137:761–9.
3. Sanchez-Sotelo J, Baghdadi YMK, Morrey BF. Primary linked semiconstrained total elbow arthroplasty for rheumatoid arthritis: a single-institution experience with 461 elbows over three decades. J Bone Joint Surg Am. 2016;98:1741–8.
4. Morrey BF, Bryan RS. Complications of total elbow arthroplasty. Clin Orthop Rel Res. 1982;170:204–12.
5. Goldberg SH, Urban RM, Jacobs JJ, King GJW, O'Driscoll SW, Cohen MS. Modes of wear after semiconstrained total elbow arthroplasty. J Bone Joint Surg Am. 2008;90:609–19.
6. Voloshin I, Schippert DW, Kakar S, Kaye EK, Morrey BF. Complications of total elbow replacement: a systematic review. J Shoulder Elb Surg. 2011;20:158–68.
7. Park S-E, Kim J-Y, Cho S-W, Rhee S-K, Kwon S-Y. Complications and revision rate compared by type of total elbow arthroplasty. J Shoulder Elb Surg. 2013;22:1121–7.
8. Little CP, Graham AJ, Carr AJ. Total elbow arthroplasty: a systematic review of the literature in the English language until the end of 2003. J Bone Joint Surg Br. 2005;87:437–44.
9. Figgie HE, Inglis AE, Mow C. A critical analysis of alignment factors affecting functional outcome in total elbow arthroplasty. J Arthroplast. 1986;1:169–73.
10. Kim JM, Mudgal CS, Konopka JF, Jupiter JB. Complications of total elbow arthroplasty. J Am Acad Orthop Surg. 2011;19:328–39.
11. Throckmorton T, Zarkadas P, Sanchez-Sotelo J, Morrey B. Failure patterns after linked semiconstrained total elbow arthroplasty for posttraumatic arthritis. J Bone Joint Surg Am. 2010;92:1432–41.
12. Morrey BF, Bryan RS. Infection after total elbow arthroplasty. J Bone Joint Surg Am. 1983;65:330–8.
13. Somerson JS, Morrey ME, Sanchez-Sotelo J, Morrey BF. Diagnosis and management of periprosthetic elbow infection. J Bone Joint Surg Am. 2015;97:1962–71.
14. Sanchez-Sotelo J. Primary elbow arthroplasty: problems and solutions. Shoulder Elbow. 2017;9:61–70.
15. Schoch BS, Werthel J-D, Sánchez-Sotelo J, Morrey BF, Morrey M. Total elbow arthroplasty for primary osteoarthritis. J Shoulder Elb Surg. 2017;26:1355–9.
16. Ernstbrunner L, Hingsammer A, Imam MA, Sutter R, Brand B, Meyer DC, et al. Long-term results of total elbow arthroplasty in patients with hemophilia. J Shoulder Elb Surg. 2018;27:126–32.
17. Dale TM, Saucedo JM, Rodriguez-Merchan EC. Total elbow arthroplasty in haemophilia. Haemophilia. 2018;24:548–56.
18. Gschwend N, Simmen BR, Matejovsky Z. Late complications in elbow arthroplasty. J Shoulder Elb Surg. 1996;5:86–96.
19. Yamaguchi K, Adams RA, Morrey BF. Infection after total elbow arthroplasty. J Bone Joint Surg Am. 1998;80:481–91.
20. Spormann C, Achermann Y, Simmen BR, Schwyzer H-K, Vogt M, Goldhahn J, et al. Treatment strategies for periprosthetic infections after primary elbow arthroplasty. J Shoulder Elb Surg. 2012;21:992–1000.

Revision Total Elbow Arthroplasty: Surgical Technique

11

Pablo Vadillo-Cardona, E. Carlos Rodríguez-Merchán, and Samuel Antuña

11.1 Introduction

The total number of elbow replacements performed worldwide has increased significantly in the last years with an estimated annual growth rate of 6.4% between 1993 and 2007 [1]. Regarding indications, there has been a clear shift in the population undergoing a total elbow arthroplasty. In the past, the vast majority of replacements were performed in rheumatoid patients but more recently most of them are implanted in post-traumatic arthritis. The reported revision rate of elbow arthroplasty performed for post-traumatic arthritis is 13% [2].

There is scarce information in the literature regarding techniques and outcomes of revision elbow arthroplasty. Many of the reported procedures are based on hip and knee revision arthroplasty principles. However, there are some important differences that must be considered. Bone stock in the upper extremity is poorer, and there is less soft tissue coverage that increases the risk of wound infection. Additionally, the proximity of neuromuscular structures nerves makes this surgery more risky during manipulation and cementation [3].

11.2 Surgical Technique

11.2.1 Exposure

Managing the skin is of paramount importance in revision elbow arthroplasty. When there are several previous incisions, the closest to the posterior midline is commonly used. Full thickness skin flaps are developed laterally and medially. When the ulnar nerve was previously transposed, it is only identified proximally, but a formal dissection is not performed. In the atypical scenario of an ulnar nerve which was not previously transposed, it is fully dissected, and most of times it is subcutaneously transposed.

Managing the triceps is a crucial step. Whenever possible, its attachment to the olecranon should be preserved. The Alonso-Llames or bilatero-tricipital approach is the preferred approach if it allows adequate exposure of the distal humerus and proximal ulna. When the surgeon judges that maintaining the triceps attachment may render the procedure too difficult and risky, a Bryan-Morrey approach may be elected. In this approach, the triceps is reflected laterally from the olecranon in continuity of the ulnar periosteum and the fascia of the forearm along with the anconeus [4]. Triceps split approaches are

P. Vadillo-Cardona (✉) · E. C. Rodríguez-Merchán · S. Antuña
Department of Orthopedic Surgery,
"La Paz" University Hospital, Madrid, Spain

E. C. Rodríguez-Merchán (ed.), *Revision Total Joint Arthroplasty*,
https://doi.org/10.1007/978-3-030-24773-7_11

usually reserved for patients with poor triceps tissue, typically after multiple surgeries [5]. When the lateral approach to the triceps is extended proximally, the radial nerve must be identified and protected.

11.2.2 Cement Removal and Insertion of a Revision Component

Aseptic loosening usually requires cement removal and implantation of a new component. In order to remove the cement mantle, a 2-mm long burr, flexible reamers or a drill can be used. As bone quality in revision cases is usually poor, cement fragments that are well adhered but do not interfere with new stem insertion could be left in place. When the cement interface is solid and cement removal cannot be achieved through the medullary canal, a cortical window or split may be needed.

Loosening of the humeral or ulnar stems is commonly associated with cortical thinning or ballooning, placing the shaft at risk for perforation during surgery. Intra-operative fluoroscopy could be useful to control insertion and penetration of the sclerotic bone with an intra-medullary guide wire. A cannulated drill or reamer can be then safely used to widen the canal.

11.2.3 Revision Component with Intact Cement Mantle

In cases with intact cement mantle after implant removal, the "cement-within-cement technique" can be used. In order to be able to implant the new stem, the cavity is enlarged using drills and flexible reamers. The medullary canal is irrigated to remove blood and other debris, new cement is introduced and the revision component is inserted. Athwal et al. reported similar results in two groups of patients with and without cement removal, with significant shorter surgical time with the "cement on cement technique" [6].

11.2.4 Management After Periprosthetic Elbow Infection

Infection after total elbow arthroplasty can be a devastating complication. The rate of infection ranges from 3% to 8% [7, 8]. Infections rarely present with systemic symptoms or significant abnormalities in serum markers. When pain and radiographic signs of loosening are present after elbow replacement, infection should be suspected and joint aspiration is recommended. If the aspiration is negative, an open or arthroscopic biopsy should be considered to rule out infection [9].

The treatment of periprosthetic elbow infection includes different strategies:

11.2.4.1 Infection Suppression

Suppressive antibiotic therapy is only an option in high morbidity patients not suitable for an aggressive surgical procedure and provided the isolated microorganisms are sensitive to an available antibiotic with acceptable tolerance [10–12].

11.2.4.2 Resection Arthroplasty

Implant removal has been the standard of treatment for infection after elbow replacement for many years. This option should be considered in low demand patients, patients with previous failed treatment or severe bone loss (Fig. 11.1).

11.2.4.3 Debridement and Implant Retention

Debridement and implant retention is the treatment of choice for patients with well-fixed components and an acute infection (less than 3 months) not caused by *S. epidermidis*. Yamaguchi et al. [7] reported the results of this approach in 14 patients in whom they unlinked both components, replaced the polyethylene and performed a throughout debridement acutely. Local antibiotics, including tobramycin, were placed in the joint and also intravenous antibiotic was administered. Patients underwent several debridements until the joint was considered free of infection and the cultures were negative. This treatment approach was only effective in 50% of

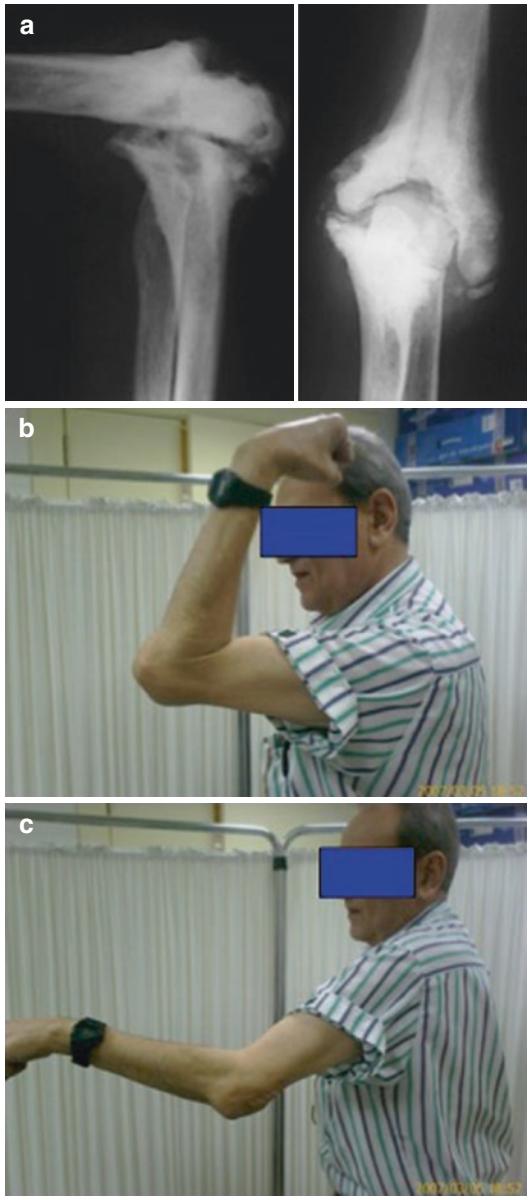

Fig. 11.1 Elbow resection due to infection with a good result: (**a**) anteroposterior (AP) and lateral view of resection arthroplasty; (**b**) flexion and (**c**) extension range of motion at final follow-up

cases. None of the patients infected with *S. epidermidis* healed.

11.2.4.4 One-Stage Revision

One-stage revision knee or hip arthroplasty has been successful in some scenarios. However, there is little information available on this approach for treating infections after total elbow replacement.

11.2.4.5 Two-Stage Revision

Two-stage revision arthroplasty is considered the gold standard in the treatment of periprosthetic elbow infections. After the humeral and ulnar components are extracted, the whole cement mantle is removed. Usually, a cement spacer loaded with antibiotics is placed in the joint. After a minimum of 6 weeks of intravenous antibiotic treatment adapted to the isolated microorganism, patients are considered for re-implantation. Before re-implantation, all blood markers must be within normal limits and joint aspiration or open biopsy must be negative. The reported success rate of two-two-stage re-implantation is between 70% and 90% [13, 14].

In most cases requiring several surgical procedures to address an infection, patients will present with significant bone loss. Surgeons dealing with this problem must be prepared to restore bone stock with bone struts, impaction grafting techniques or allograft-prosthetic composites depending on the specific situation.

11.2.5 Management of Bone Loss

Failed elbow replacement commonly presents with significant bone loss. Bone reconstruction strategies include augmentation with bone struts; impaction grafting for expanded, contained, cavitary defects and the use of allograft-prosthetic composites for large segmental defects.

Distal humerus bone loss is defined as grade I when the subchondral architecture is intact, grade II when the medial and lateral supracondylar columns are preserved, grade III when either the medial or the lateral columns were absent and grade IV when the entire distal humerus to or proximal to the level of the olecranon fossa is absent [15].

Revision humeral stems could accommodate up to 8 cm of distal humeral bone loss by using longer implants with an extended anterior flange. Larger defects may require some degree of humeral shortening. According to the location

and degree of bone loss, several surgical strategies can be implemented.

11.2.5.1 Impaction Grafting

Impaction grafting is a reliable technique for treating osteolysis in patients undergoing revision total elbow arthroplasty when there are expanded, contained, cavitary defects. The technique is very similar to the one described for reconstructing the proximal femur in revision hip arthroplasty.

Bone stock is restored by filling the medullary canal with impacted morselized allograft. If any segmental cortical defect of cortical thinning is present, it must be previously augmented with allograft bone struts. Once the canal is cleaned and the cancellous allograft introduced in the medullary canal, it is sequentially impacted with a trial component. The defect surrounding the stem must be tightly packed in order to add stability to the final construct. Once stabilized, the trial component is removed, gentamicin loaded low-viscosity cement is injected and the definitive component implanted. Morrey et al. popularized the use of two tubes when impacting the bone graft, the outer tube could be the standard femoral cementation tube and, the inner one, the thinner cement injector tube used in elbow replacement. The allograft is pressed around the outer tube, and both tubes are removed while cement is injected.

Loebenberg et al. [16] published their results with elbow impaction grafting in 12 patients. After a minimum 2 years follow-up, eight patients showed radiographic restoration of bone quality without signs of loosening, and four patients required new revision surgery: for loosening in two patients, and infection and fracture in one patient each.

More recently, Rhee et al. [17] analyzed 16 cases of revision total elbow arthroplasty with impaction grafting in aseptic loosening. At the latest follow-up, 15 of the 16 patients showed significant improvement. Only two patients required further surgery: one periprosthetic humeral fracture and one superficial infection that resolved with debridement.

11.2.5.2 Allograft Bone Struts

Bone strut allografts are generally used in cortical defects. Depending on the size, location and morphology of the defect, struts could be used to cover a discrete cortical deficiency, bypass a fracture or to augment a thinned cortex during impaction grafting. Allograft struts have also been used to augment a deficient olecranon to provide a good triceps attachment site [18].

The source of the allograft should be selected according to the size of the patient, the characteristics of the bony defect and the bone affected. A large structural defect in a small person could be treated with a fibular allograft while the same defect in a larger person might require a femoral shaft allograft.

Fixation of the struts requires enough exposure to ensure adequate contact between the allograft and the host bone to facilitate incorporation. Usually circumferential 16- or 18-gauge wires are used to fix the allograft to the bone (Fig. 11.2).

Sanchez-Sotelo et al. [3] demonstrated satisfactory results in the treatment of periprosthetic humeral fractures around a loose humeral component using strut allograft augmentation in revision arthroplasty. Clinical and radiographic results were satisfactory and fracture union was achieved in 10 of 11 patients. However, the complication rate was elevated with four patients reporting one complication and two patients reporting two complications. Complications included olecranon fracture, permanent ulnar nerve injury, periprosthetic humeral fracture and a case of triceps insufficiency.

Kaminemi and Morrey [18] reported their experience treating aseptic failure of total elbow arthroplasty associated with proximal ulnar bone deficiency with allograft bone struts. In 21 patients, the mean Mayo Elbow Performance Score (MEPS) improved from 34 pre-operatively to 79 points at the time of latest follow-up (2–11 years). Eight patients (38%) suffered a complication.

Foruria et al. [19] reported on 21 patients with periprosthetic ulnar fractures associated with loosening that were treated with revision of the

Fig. 11.2 Massive defect treated with strut grafts (5 years follow-up): (**a**) anteroposterior (AP) radiograph of the pre-operative bone defect; (**b**) intra-operative view of the reconstruction with bone struts; (**c**) AP and (**d**) lateral view after open reduction and internal fixation (ORIF); (**e**) AP and (**f**) lateral view of the humerus 5 years after surgery; (**g**) flexion and (**h**) extension range of motion of the patient at final follow-up

ulnar stem and strut allografts in 12 cases (eight of them with associated impaction grafting), three impaction grafting alone and five with allograft ulnar prosthesis composite. In two elbows, fracture fixation was achieved with a revision longer stem only. All patients had fracture healing and postoperative MEPS of 82 points. Complications included four infections, one ulnar component loosening and one case of transient dysfunction of median and radial nerves.

11.2.5.3 Allograft-Prosthetic Composites (APC)

Allograft composites consist of a hybrid structure composed of a segmental bone allograft with a cemented prosthetic stem inside. The distal part of the stem is left free to be cemented into the native bone. This technique is mostly used in severe bone loss, typically leading to olecranon insufficiency or distal humerus resorption.

Allograft selection is made according to the affected bone. Humeral allografts are commonly used in humeral defects and ulnar or fibular allografts in ulnar defects. The length of the graft can be estimated by sizing the length of the contralateral side. Composite-host bone union is typically made step-cut to increase the contact area and promote healing.

Fixation is achieved by cementing the implant into the prosthetic composite and also in the host bone. The implant should bypass at least two cortical diameters' length of the prosthetic component into the host bone. Cancellous bone graft can be packed around the junction. Stability may be increased by plating or a cerclage fixation. In proximal ulnar reconstruction, drill holes could be used to reattach the triceps.

Renfree et al. [20] reported their results in 14 allograft-prosthetic composites with a mean follow-up of 6.5 years. They demonstrated 79% radiographic healing but only four patients achieved a functional range of motion and five patients failed and required another operation.

Mansat et al. [21] reported the results of revision elbow arthroplasty with an APC in 13 elbows. Eighty-five percent of cases achieved union. The MEPS scale was excellent for four elbows, good for three, fair for one and poor for five. Range of motion was limited to an average of 28° of extension to 125° of flexion. The revision rate was 38% and the complication rate was high, infection being the most common one.

In a recent study, Morrey et al. [22] updated the Mayo Clinic experience with 25 patients. They described three techniques of APC reconstruction:

- Type-I (intussusception): the cemented implant and the allograft were inserted into the host bone canal. It is indicated in contained defects with intact cortical bone.
- Type-II (strut-like coaptation): similar to the original technique, the implant and the allograft composite are fixed to the host bone in a step-cut osteotomy. Two cortical widths are left nude to be fixed to the native bone. It is used when there is a major cortical defect at the implant insertion site.
- Type-III (side-to-side): a side-to-side contact between the cortices of the allograft composite and the native bone is formed.

Morrey et al. demonstrated allograft incorporation in 92% of cases and an improvement in MEPS from 30 points to 84. However, there were eight major and four minor complications with nine re-operations in six patients.

APC reconstruction may be a valuable tool in patients with catastrophic total elbow arthroplasty failure with severe bone loss and where other options are not feasible. Union rates seem to be high but complications are also very common. Functional results after APC reconstruction are better than after resection arthroplasty; however, it is preferable whenever possible to use bone struts for bone augmentation.

11.2.6 Management After Periprosthetic Elbow Factures

Addressing periprosthetic fractures is among the most demanding surgeries in revision total elbow

arthroplasty. The rate of periprosthetic fractures after elbow replacement is approximately 5% [3]. As it has happened in other joints, we will probably see an increased incidence with time as the complexity of primary and revision surgery becomes more common.

The Mayo Clinic classification categorizes periprosthetic fractures around the elbow into three types: according to location, implant stability and bone loss [23].

- Type I fractures involve the humeral condyles or olecranon and are the most common.
- Type II fractures are located around the stem, and they are subdivided in three types according to the stability of the stem and the bone stock quality.
  - II1: fractures around a well-fixed stem with good bone stock.
  - II2: fractures around a loose implant with good bone stock.
  - II3: fractures around a loose implant with significant bone loss.
- Type III fractures are proximal to the stem tip in the humerus or distal in the ulna.

11.2.6.1 Type I Fractures

In the absence of compromised function or stability, these fractures could be treated non-surgically with immobilization. Condyle fractures occurring with a linked implant could be treated just by excision by releasing the muscle attachments and repairing the soft tissues to the triceps fascia. Olecranon fractures interrupting the extensor mechanism should be treated surgically. The preferred method of fixation is a tension band with wires placed dorsally, parallel to the cortex.

11.2.6.2 Type II Fractures

Treatment of type II fractures is dictated by the stability of the stem and the amount of bone loss. Fractures around a well-fixed stem do not need a prosthesis revision. Un-displaced fractures should be treated with splinting and immobilization. When the fracture is displaced or malaligned, surgery is recommended. 14- to 16-gauge cerclage wires are usually preferred. Plates are only used when there is optimal bone stock; and unicortical screws are used around the stem. Allograft bone struts could also be used to improve fracture alignment and to supplement bone stock.

Fractures around a loose stem require implant revision. The length of the revision implant should bypass the fracture line less by two cortical widths, and it should be cemented into healthy bone. In cases with very thin cortex or precarious stability, allograft bone struts are used. Before deciding the appropriate length of the strut, a trial reduction should be performed to avoid impinging in flexion. Ideally, strut grafts should extend beyond the fracture line at least two cortical diameters. Humeral fractures usually require two struts; the anterior strut should be shorter than the posterior one and should be used to accommodate the anterior flange of the prosthesis. Ulnar fracture struts are placed laterally or medially to avoid subcutaneous prominence (Fig. 11.3).

Before placing the struts, the final implant is cemented to avoid cement extravasation. Cement extravasation may reduce the contact area between host bone and the allograft strut interfering with healing; it can cause iatrogenic damage to nerves or may limit motion. Struts are fixed usually with cerclage cables. In humeral fractures, four cerclages wires are typically used, two proximal and two distal to the fracture.

Fractures associated with significant bone loss usually occur after progressive osteolysis and bone resorption around the stem. Bone augmentation techniques are needed in addition to fracture stabilization. A combination of bone struts and impaction grafting are commonly required to restore bone stock and provide stability. In cases of severe bone loss, grade IV or absence of olecranon, an APC reconstruction may be the only option.

11.2.6.3 Type III Fractures

Shaft fractures beyond the tip of the stem can be treated with immobilization. Surgery is recommended if satisfactory alignment is not achieved (Fig. 11.4).

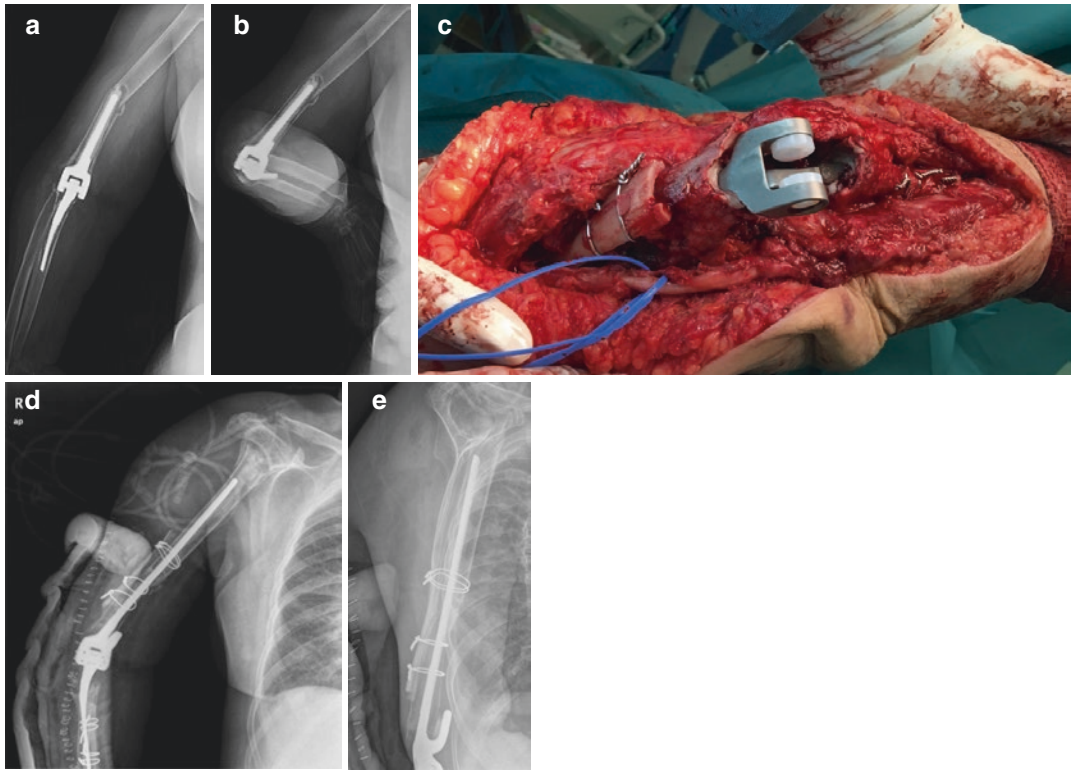

Fig. 11.3 Periprosthetic aseptic loosening treated with implant revision and bone struts: (**a**) anteroposterior (AP) and (**b**) lateral view of periprosthetic aseptic loosening; (**c**) intra-operative view of the reconstruction; (**d**) AP and (**e**) lateral view after open reduction and internal fixation (ORIF)

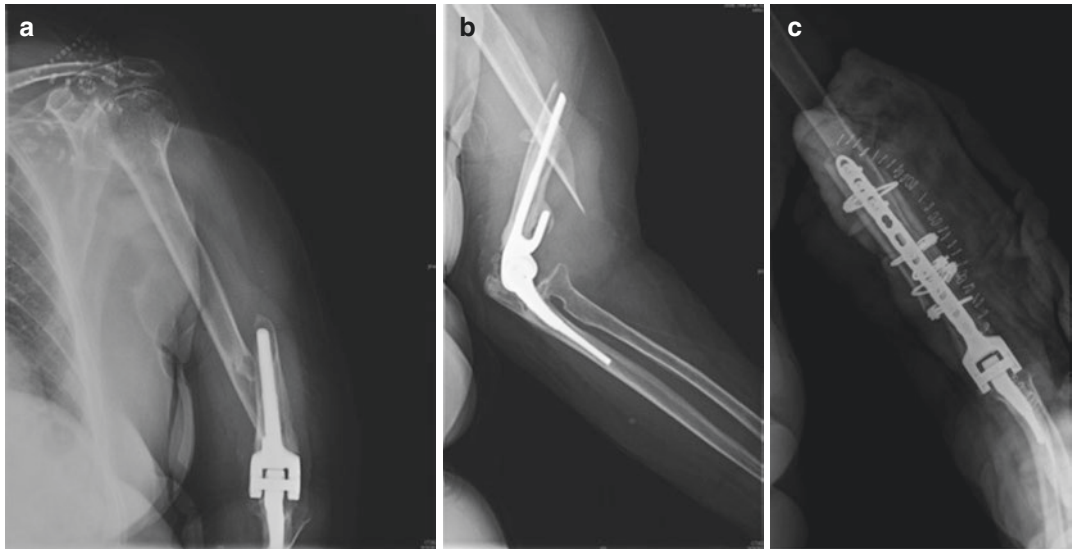

Fig. 11.4 Periprosthetic fracture treated by means of open reduction and internal fixation (ORIF) with an excellent result: (**a**) anteroposterior (AP) and (**b**) lateral view of the fracture; (**c**) AP and (**d**) lateral view after ORIF; (**e**) AP and (**f**) lateral view of the humerus 5 years after surgery

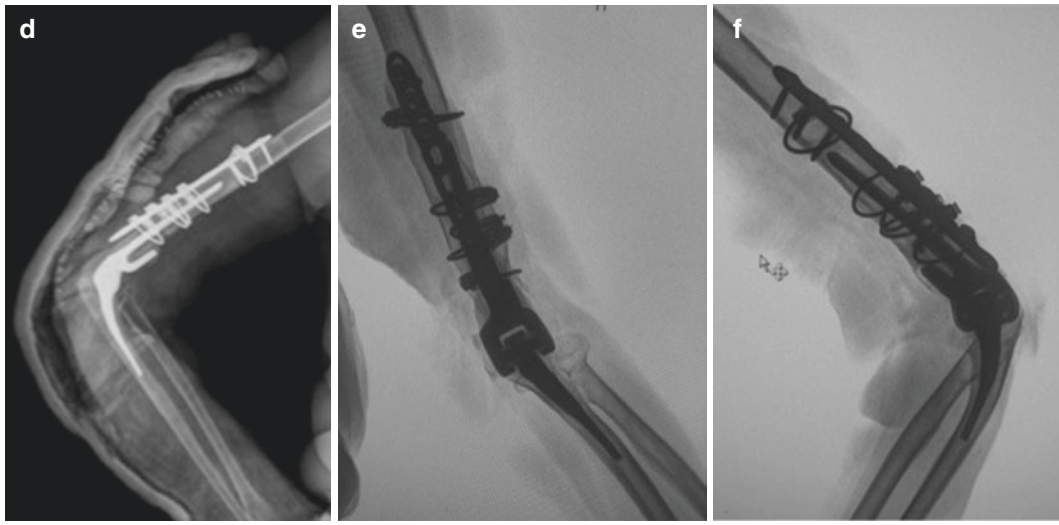

Fig. 11.4 (continued)

11.3 Conclusions

The available literature in revision elbow arthroplasty is scarce. Most of the principles followed in treating these patients have been extrapolated from hip and knee revision arthroplasties. Infection, fractures and osteolysis with bone loss are the most common reason for revision elbow arthroplasty bone loss.

Infection is a catastrophic complication after elbow arthroplasty. The diagnosis of infection should be based on clinical suspicion and careful interpretation of blood tests. When infection is suspected, cultures of joint aspiration or even arthroscopic or open biopsies are indicated. The current recommendations for dealing with an infected elbow arthroplasty include debridement with retention of well-fixed implants in acute infections not caused by *S. epidermidis* and resection with staged reimplantation in the rest of cases. Allograft-prosthetic composite reconstruction is used only in massive bone loss not amenable to other form of reconstruction. Resection arthroplasty is still a valid option in extremely frail and low demand patients.

Revision total elbow arthroplasty in the context of periprosthetic fractures and bone loss entails substantial risks. These include nerve injury, infection, implant loosening and wound complications. These risks could be minimized with a meticulous pre-operative planning, adequate exposure and nerve protection. The risk of non-union and implant loosening may be reduced by delicate surgical techniques and the use of strut allograft, plate fixation or allograft-prosthetic composites. These complex reconstructive procedures can yield to a good result, restoring elbow function and eliminating pain. Strut allografts should be used to address cortical defects or if a thin cortex is present. Struts are also very effective as a supplement for fracture healing with satisfactory results. Impaction grafting and allograft composites are useful to augment bone stock but due to the high number of complications reported their use should be judicious.

References

1. Day JS, Lau E, Ong KL, Williams GR, Ramsey ML, Kurtz SM. Prevalence and projections of total shoulder and elbow arthroplasty in the United States to 2015. J Shoulder Elb Surg. 2010 Dec;19:1115–20.
2. Cross MB, Cicalese E, Nam D, McArthur BA, Lipman JD, Figgie MP. Results of custom-fit, noncemented, semiconstrained total elbow arthroplasty for

inflammatory arthritis at an average of eighteen years of follow-up. J Shoulder Elb Surg. 2014;23:1368–73.
3. Sanchez-Sotelo J, O'Driscoll S, Morrey BF. Periprosthetic humeral fractures after total elbow arthroplasty: treatment with implant revision and strut allograft augmentation. J Bone Joint Surg Am. 2002;84:1642–50.
4. Bryan RS, Morrey BF. Extensive posterior exposure of the elbow. A triceps- sparing approach. Clin Orthop Relat Res. 1982;(166):188–92.
5. Alonso-Llames M. Bilaterotricipital approach to the elbow. Its application in the osteosynthesis of supra-condylar fractures of the humerus in children. Acta Orthop Scand. 1972;43:479–90.
6. Athwal GS, Morrey BF. Revision total elbow arthroplasty for prosthetic fractures. J Bone Joint Surg Am. 2006;88:2017–26.
7. Yamaguchi K, Adams RA, Morrey BF. Infection after total elbow arthroplasty. J Bone Joint Surg Am. 1998;80:481–91.
8. Jenkins PJ, Watts AC, Norwood T, Duckworth AD, Rymaszewski LA, McEachan JE. Total elbow replacement: outcome of 1,146 arthroplasties from the Scottish Arthroplasty Project. Acta Orthop. 2013;84:119–23.
9. Somerson JS, Morrey ME, Sanchez-Sotelo J, Morrey BF. Diagnosis and management of periprosthetic elbow infection. J Bone Joint Surg Am. 2015;97:1962–71.
10. Wolfe SW, Figgie MP, Inglis AE, Bohn WW, Ranawat CS. Management of infection about total elbow prostheses. J Bone Joint Surg Am. 1990;72:198–212.
11. Eid AJ, Berbari EF, Sia IG, Wengenack JL, Osmon DR, Razonable RR. Prosthetic joint infection due to rapidly growing mycobacteria: report of 8 cases and review of the literature. Clin Infect Dis. 2007;45:687–94.
12. Pradier M, Robineau O, Boucher A, Titecat M, Blondiaux N, Valette M, Loïez C, Beltrand E, Nguyen S, Dézeque H, Migaud H, Senneville E. Suppressive antibiotic therapy with oral tetracyclines for prosthetic joint infections: a retrospective study of 78 patients. Infection. 2018;46:39–47.
13. Cheung EV, Adams RA, Morrey BF. Reimplantation of a total elbow prosthesis following resection arthroplasty for infection. J Bone Joint Surg Am. 2008;90:589–94.
14. Peach CA, Nicoletti S, Lawrence TM, Stanley D. Two-stage revision for the treatment of the infected total elbow arthroplasty. Bone Joint J. 2013;95-B:1681–6.
15. King GJ, Adams RA, Morrey BF. Total elbow arthroplasty: revision with use of a non-custom semiconstrained prosthesis. J Bone Joint Surg Am. 1997;79:394–400.
16. Loebengerg MI, Adams R, O'Driscoll SW, Morrey BF. Impaction grafting in revision total elbow arthroplasty. J Bone Joint Surg Am. 2005;87:99–106.
17. Rhee YG, Cho NS, Parke CS. Impaction grafting in revision total elbow arthroplasty for aseptic loosening and bone loss: surgical technique. J Bone Joint Surg Am. 2013;3:e17.
18. Kamineni S, Morrey BF. Proximal ulnar reconstruction with strut allograft in revision total elbow arthroplasty. J Bone Joint Surg Am. 2004;86:1223–9.
19. Foruria AM, Sanchez-Sotelo J, Oh LS, Adams RA, Morrey BF. The surgical treatment of periprosthetic elbow fractures around the ulnar stem following semiconstrained total elbow arthroplasty. J Bone Joint Surg Am. 2011;93:1399–407.
20. Renfree KJ, Dell PC, Kozin SH, Wright TW. Total elbow arthroplasty with massive composite allografts. J Shoulder Elb Surg. 2004;13:313–21.
21. Mansat P, Adams RA, Morrey BF. Allograft-prosthesis composite for revision of catastrophic failure of total elbow arthroplasty. J Bone Joint Surg Am. 2004;86:724–35.
22. Morrey ME, Sanchez-Sotelo J, Abdel MP, Morrey BF. Allograft-prosthetic composite reconstruction for massive bone loss including catastrophic failure in total elbow arthroplasty. J Bone Joint Surg Am. 2013;95:1117–24.
23. O'Driscoll SW, Morrey BF. Periprosthetic fractures about the elbow. Orthop Clin North Am. 1999;30:319–25.

Revision Total Elbow Arthroplasty: Complications and Results

12

Raul Barco

12.1 Introduction

As the number of total elbow arthroplasty (TEA) has increased worldwide so has the number of expected revisions [1]. The number of procedures performed for inflammatory arthritis has decreased while the number of procedures performed for trauma or posttraumatic sequelae has increased. This shift in the indication for TEA may have an impact on long-term survival as posttraumatic patients are usually younger and more active, so failures for loosening might increase in the future. Additionally, these cases may be affected by the deficient distal humerus and proximal ulna, which poses a specific risk for revision [2]. This increased burden of surgery poses specific risks to hospital systems and surgeons as the complexity of the techniques to address these problems is difficult and is not without complications [3–5].

In this chapter, we address the current results of revision arthroplasty, its complications, and some of the challenges for the future. If TEA is still considered an infrequent procedure for most of the surgeons performing it, this is only increased with revision TEA. Not only the frequency but the surgical challenges of a revision procedure are enormous, and as Dee wrote in 1980, "the failed total prosthesis presents a formidable challenge." Sadly, this has not changed in all these years, and the increased complexity of the surgical procedure with the use of very specific techniques for bone reconstruction, the need for extended approaches with nerve dissection and protection, the use of longer implants, and the absence of anatomical references to guide proper alignment of the prosthetic elbow still remain.

Causes for revision include loosening, infection, instability, and component failure [3–5]. Naturally, specific designs have a specific list of problems (Table 12.1). Additionally, nerve entrapment, triceps failure, and stiffness (with or without ankylosis) may be a cause for reoperation. Periprosthetic fractures are an additional complication that increases with longer follow-up [6, 7]. Revision surgery has a different approach depending on the presence of infection and is affected by the presence of bone loss or periprosthetic fracture. Strategies for the recon-

Table 12.1 Causes for revision surgery after total elbow arthroplasty (TEA)

Linked TEA	Unlinked TEA
Bushing wear	Instability
Aseptic loosening Infection Periprosthetic fracture Stiffness Ulnar nerve problems	

R. Barco (✉)
Upper Limb Unit, Department of Orthopedic Surgery, "La Paz" University Hospital, Madrid, Spain

E. C. Rodríguez-Merchán (ed.), *Revision Total Joint Arthroplasty*,
https://doi.org/10.1007/978-3-030-24773-7_12

struction of bony deficiency include strut augmentation, impaction grafting, and the use of allograft-prosthetic composite (APC) reconstruction, mostly using hinged designs. Thus, it is difficult to singularly address results of revision TEA as a single entity.

In a recent systematic review addressing the outcomes of revision TEA including 21 studies published between 1987 and 2017, Geurts et al. reported on 532 patients with a mean age of 61 years of age and a mean follow-up of 65 months after revision surgery, which occurred after a mean of 77 months after the index TEA. In 79% of the cases, either the linked Coonrad-Morrey (59%) or the unlinked Souter-Strathclyde design was used in these reports so the information may not apply correctly to other designs [8]. Patient pain improved from 3.9 preoperatively to 1.5 postoperatively ($p < 0.001$) at rest and from 6.3 to 3.1 with activity ($p < 0.001$). Flexion improved from 119° to 128° and loss of extension improved from 35° to 30° for an improvement in the total arc of flexion from 87° to 99° ($p < 0.001$). Total pronation and supination arc of motion improved from 124° to 134° ($p < 0.001$) with a significant improvement of all parameters of the Mayo Elbow Performance Score (MEPS) score. When comparing results between linked and unlinked implants, the results were better for the linked implant as shown by MEPS, extension deficit, arc of flexion-extension, and pronation. Complications were reported at a similar rate (46% for the linked design against 45% for the unlinked one). However, linked prostheses have more reoperations than unlinked implants (26% vs. 20%), the indications being similar. Contraindications to the use of an unlinked implant are having insufficient bone stock and inadequate soft tissues, which may introduce selection bias in the comparison. Forty-four percent (44%) of patients suffered at least one complication, the most frequent ones in the order of importance being aseptic loosening (22%), transient nerve symptoms (21%), and periprosthetic fracture (15%) There were 128 reoperations in 116 cases (21.8%) consisting in a second revision in 57% of the cases, followed by a second revision with bone grafting (8%), removal of the prosthesis (22%), cerclage wiring (4%), a cement spacer replacement (4%), and debridement with antibiotics (4%). The authors suggest that in the revision setting a linked design might be a better option, and with the available numbers, it precludes a subsequent analysis according to the different indications for the index or revision surgery. Table 12.2 summarizes main results of revision for aseptic loosening [7, 9–11].

We have analyzed the outcomes according to the most common clinical scenarios in revision TEA.

12.2 Situations with No Bony Deficiency

Loosening occurs from primary failure of the bone-cement interface or secondarily due to particulate debris from polyethylene wear associated with particular designs (Coonrad-Morrey precoated stem) [12]. If polyethylene (PE) wear is indeed the problem, young patients, high activity level, type of PE and, mostly, linked designs in which the PE is used as a bushing are at an increased risk of developing this problem. Particulate debris is known to cause synovitis and osteolysis. Situations which increase the stress on the cement-bone interface such as deformity, implant malposition, impingement, obesity, activity level, and structural deficiency only increase the risk of this complication [13–19]. While most bushings have a PE part, the number of revisions for isolated bushing wear is low in the literature, and many consider loosening associated with the precoat ulnar component than to osteolysis (Table 12.3) [19–21]. Particulate debris disease can be clinically silent until mechanical impingement and metallosis produce symptoms at which time the amount of bone loss may be variable but can be significant.

Fracture of the stem is a rare cause for revision typically without loss of host bone and can occur at both the humerus and the ulna. There is scarce information, but Athwal et al. described their experience in 24 patients presenting with 27 TEA in a single institution for a prevalence of 0.65% of humeral component fracture and 1.2% of ulnar

Table 12.2 Revision for aseptic loosening

Author	Patients (*N*)	Age at surgery (mean)	Follow-up (months)	MEPS	Survival rate	Complications/observations
Sanchez-Sotelo et al. [7]	5		36	Functional		4 additional humeral fractures 1 olecranon fracture 1 triceps failure 1 permanent ulnar nerve injury
Shi et al. [10]	30	65	68	85+/−16	11/30 5-year survival rate 64%	64% moderate or severe pain
Sneftrup et al. [9]	24 elbows in 23 patients	62	15–88	85 (45–100)	83.1% at 5-year follow-up	13/24 elbows complication with 8 reoperations in 4 elbows. 5 patients showed bushing wear 4 prostheses revised 3 ulnar neuropathies, 3 radial neuropathies (2 motor), 1 triceps insufficiency
Malone et al. [11]		66	91.2	85+/−16	5-year survival rate 64% 7 revisions out of 11 failures in RhA (3), posttraumatic arthritis (2), trauma (1) OA (1) for humeral loosening (3), broken bushing (2), triceps avulsion (1), ulnar loosening (2), periprosthetic fracture (2), ulna and distal humerus	5-year survival rate 64% Additional complications include flexion contracture >45 (3), ulnar neuropathy (4), intraoperative fractures (2), triceps avulsion (1)

N number, *MEPS* mayo elbow performance score, *RhA* rheumatoid arthritis

Table 12.3 Revisions for isolated bushing wear

Author	Patients	Age (mean at initial TEA)	Primary TEA	Revision	Time to revision	Revised component	Observations
Wright et al. [19]	10	54	Posttraumatic arthritis, nonunion, RhA, tumor	Bushing wear	60 months	Ulna: 4 Humerus:1 Ulna and humerus:2 Bushing wear: 3	
Lee et al. [20]	12	44	Posttraumatic, RhA, deficient columns	Bushing wear	7.9 years	None	Associated osteolysis in 4 humerus and 4 ulnas
Mansat et al. [21]	15	55	Posttraumatic arthritis, nonunion, RhA, psoriatic arthropathy, septic arthritis sequelae	Bushing wear in 7 (severe in 2)		Bushing exchange: 2 (same patient); 1 RA	Revision-free survival at 10 years 90% 10 complications with 3 revisions

TEA total elbow arthroplasty, *RhA* rheumatoid arthritis, *RA* resection arthroplasty

component fracture [22]. Of note, the ulnar component fracture was seen mostly with the porous-coated stem of the Coonrad-Morrey prostheses and since the design change to the plasma sprayed this complication virtually disappeared. The mean time between the index operation and the revision was 8.2 years for the humeral component and 4.6 years for the ulnar component. The authors described a technique to progressively expand the cortical cement mantle after extraction of the fracture stem and a revision with a cement-in-cement technique in 14 cases. In the remainder, all the cement was extracted with or without the use of cortical windows (three cases). The bushings were exchanged for wear in five cases. The clinical results at 5 years follow-up were similar for both techniques (traditional vs. cement-in-cement) with comparable MEPS (78 vs. 82), corresponding to excellent results in eight patients, good in five, fair for six, and poor for two. Nineteen complications occurred in 14 patients, 7 of which were intraoperative and included intraoperative cortical perforations, 5 nerve injuries (2 permanent), 3 triceps avulsions, and 1 deep infection. Most cortical perforations were small and were treated with strut allograft and in one case with cancellous bone chips. Three transient ulnar neuropathies resolved postoperatively with one additional persistent sensory ulnar neuropathy and one postoperative radial nerve palsy in a patient that was lost to follow-up. Of the three triceps ruptures two underwent repair, and one refused further surgery. One patient sustained an olecranon fracture for the treatment of early stiffness while being manipulated during rehabilitation that required internal fixation. Another suffered a stable periprosthetic fracture that healed with bracing. One patient had bushing wear that required revision bushing exchange 41 months after the revision, another patient underwent revision of the humeral component for loosening at 51 months after the operation, and the third patient had a failure of both implants due to infection despite surgical debridement and suppressive antibiotics.

12.3 Situations with Loss of Host Bone

Surgical options for failed TEA with loss of host bone include resection, allograft, standard TEA, semi-constrained long-flanged prosthetic component, the use of a custom-made component, or use of a TEA with allograft. Specific considerations learned from revision hip surgery also apply to the elbow, including that a successful revision requires a stem that bypasses any cortical weakness or fracture, adequate distal humeral or ulnar fixation, and a viable articulation, and although on certain

situations, and if bony reconstruction is successful, one may choose a short stem. Obviously, the cause of failure of the failed TEA must be addressed. Malone et al. showed that bone loss negatively affects the longevity of a semiconstrained TEA, so different strategies have been developed to reconstruct bony deficiency [11].

Using an unlinked revision system, Ehrendorfert et al. reported on the results of 15 revision arthroplasties with bone loss of less than 4 cm without any use of bone augmentation [23]. The treatment included the use of longer Souter-Strathclyde cemented implants. The authors found a mean arc of motion of 85° with five patients showing less than 90° of arc of motion and a mean elbow performance score of 75. Five patients experienced ulnar nerve paresthesia, one had numbness, and three of those had a weak motor function, with an average score of postoperative pain of 6.9 (10 being no pain). Complications included ulnar and humeral perforation, fracture at the tip of the prosthesis and two patients having poor results due to residual instability. Curiously the authors note that the chief complaint of the patients was the impaired ability to carry.

12.4 Use of Impaction Grafting

Indications for the effective use of impaction grafting are osteolysis with contained cortical expansion (Table 12.4). As impaction grafting needs to impact bone into the distal humerus or proximal ulna, an appropriate cortical shell is a necessary prerequisite. Otherwise, this technique is contraindicated. Occasionally this technique can be combined with a strut graft to obtain a stable anterior cortex to stabilize the anterior flange of the humeral component.

Table 12.4 Indications for use of strut allograft

Humerus	Ulna
Periprosthetic fracture Reinforcement of thin cortical bone Small cortical defect	
Augmentation for anterior flange support	Augmentation of ulnar bone stock for triceps attachment

Lobenberg et al. reviewed the results of impaction grafting performed before 1997 in 12 patients with a mean follow up of 72 months [24]. Seven were rheumatoid arthritis patients, and five were posttraumatic patients. Impaction grafting was performed with the new component in three cases, and in nine cases there had been a prior surgery where revision of the prior TEA had been performed. Four patients had bone grafting at the ulna, six at the humerus, and two at both sides. Additional strut allografts were placed to span cortical effects in five patients. Eight of the 12 prostheses were in place at last follow-up. Two patients were revised for loosening, one for fracture of the ulnar component, and one patient underwent resection arthroplasty due to infection. The patients with the implant in place had an improvement in bone quality without signs of loosening. There were three more revisions at final follow-up with five excellent, four good, and three fair results.

Rhee et al. described the results of impaction grafting in 16 patients with a mean age of 58.4 years [25]. Fourteen elbows had loosening of both the humeral and ulnar component, and two elbows only had humeral loosening. Two elbows had a perforation of the humeral cortex, and one had a perforation of the ulnar cortex. Bone loss was King grade IV in seven cases, grade III in six, and grade II in three elbows. Impaction was performed in all cases with allograft and additional autograft from the iliac crest in three cases. Pain and total arc of motion improved with an improvement in MEPS from 41 points preoperatively to 82.8 points postoperatively ($p = 0.001$). The results were good or excellent in 15 cases and fair in 1. Mild graft resorption (grade I or II) was observed in all cases, and incomplete radiolucent lines were observed in 12 cases, complete radiolucent lines in 3, and probable loosening in 1 case. Additional surgery was needed in two cases.

12.5 Use of Strut Allograft

The use of struts in the femur for periprosthetic fractures and revision hip surgery has been successful because they provide similar support to

metal plates and may unite to host bone augmenting resulting bone stock. Struts are usually fixed by circumferential wire or cables, and an anterior and a posterior strut are commonly used in the humerus. Of particular importance is the engagement of the anterior flange with the anterior strut graft for added stability of the construct. The use of a flange and an anterior strut graft can make up for significant distal humerus defects. The results of this technique are summarized in Table 12.5 [7, 24, 26]. However, cost, availability, disease transmission, and the need for long exposures and surgical time for proper contouring can limit the use of the allograft [27]. Typically a strut allograft has been used with one or two struts in the humerus (anterior or anterior and posterior) and typically with a single posterior strut in the ulna although there is an occasional report of its use in a posteromedial and posterolateral fashion. Struts have been used because it is a simple and yet effective way of dealing with bone loss until the development of allograft-prosthetic composite techniques was refined. The use of strut allograft has been seldom reported in the literature.

Sanchez-Sotelo et al. described its use for the treatment of periprosthetic fractures with an associated humeral loose component (and one case of ulnar bony deficiency) [7]. Union was achieved in the majority (10/11), but one patient required a revision for aseptic humeral loosening after healing of the fracture. Eighty-eight percent of the patients achieved a functional arc of motion and slight or no pain. Complications were frequent, including triceps insufficiency, permanent ulnar nerve injury, olecranon fracture, humeral fracture, and nondisplaced humeral periprosthetic fracture.

Kamineni et al. reported on the results of strut allografts for proximal ulnar bone loss with failed TEA in 22 patients [26]. The reason to use grafts were to stabilize periprosthetic fractures, to reconstruct the proximal ulna for triceps reconstruction to support and augment an impaction grafting technique in proximal lytic ulna lesions, and to contain cortical defects. While the range of motion was not significantly improved, pain and function were much improved in these complex cases. All cases showed incorporation of at least 50% of the graft, of 50–75% in 5 elbows, and complete or almost complete in 14 elbows.

Foruria et al. in a report of ulnar periprosthetic elbows reported fracture healing in all patients with a mean follow-up of 5 years [28]. Of 21 patients, all except 3 had no pain. Complications include deep infection in three patients and one patient with ulnar loosening.

Tokunaga et al. reported the use of iliac crest bone graft with compression plating for an ulna fracture after loosening of the ulnar stem (type II fractures) [29]. The authors report on a staged protocol that involved the use of ICBG with compression plating achieving union and then proceeding to the revision of the ulnar implant with a longer stem with the use of impaction grafting. Other authors like Moro et al. have shown a lack of incorporation and increased risk of infection [27].

12.6 Use of Allograft-Prosthetic Composite (APC)

In the presence of massive bone loss there is an insufficient bone stock to support a conventional implant, and thus the use of bulk allograft, custom prostheses, and strut allografts have been described along with resection arthroplasty. Resection arthroplasty has been associated with decreased function according to the MEPS score, achieving 60 points. Associated with bone loss, soft tissues are frequently compromised, so a consultation to the plastic surgery department is recommended. The initial experience of the Mayo Clinic was described by Mansat et al. and showed a high rate of complication rate and a revision rate of 38% [21]. These results led to changes in the fashioning and fixation to the grafts. The use of a step cut provided increased intraoperative flexibility, and the use of side-to-side fixation with cables to the host bone permitted easy adjustment of soft tissue tension and reliable fixation. Of course, these are one of the most challenging cases in revision arthroplasty and are subject to complications (Table 12.6) [21, 30, 31].

Table 12.5 Results of impaction grafting and cortical strut grafting

Author	Type of reconstruction	Patients (*N*)	Age at surgery	Follow-up (months)	MEPS	Survival rate	Complications/ observations
Sanchez-Sotelo et al. [7]	Periprosthetic fracture around loose humeral component using strut allograft augmentation	5	NA	36	Functional ROM	10/11 united grafts 7/8 functional ROM and slight or no pain. One had moderate pain and limited motion	1 required revision 1 postoperative periprosthetic humeral fracture 1 olecranon fracture 1 triceps failure 1 permanent ulnar nerve injury
Kamineni et al. [26]	Strut allograft for ulnar osteolysis	22	NA	4 years	79		8/22 had a complication (36%)
Loebenberg et al. [24]	Severe osteolysis of distal humerus and proximal ulna treated with impaction grafting	12	57	72 (minimum 2 years)	9/12 good or excellent result	2 revisions for loosening 1 revision for fracture of ulnar component	1 infection with resection arthroplasty

N number, *MEPS* Mayo Elbow Performance score, *ROM* range of motion

Table 12.6 Allograft-prosthetic composites (APC) for bone loss in total elbow arthroplasty (TEA)

Author	Type of reconstruction	Patients (*N*)	Age at surgery	Follow-up (months)	MEPS	Survival rate	Complications/observations
Mansat et al. [21]	APC humerus (4), ulna (9 cases) using step cut technique	13	NA	42	Good and excellent in 7 of 13. Poor in five	APC removed in 3 2 nonunions of the graft	7 complications in 7 elbows with 5 revision procedures Deep infection (4)
Amirfeyz et al. [30]	Massive structural bone loss	14	64	75	74	Partial resorption in 50% grafts. Good incorporation in the ulna (7/8), bad incorporation in the ulna (1/8)	
Morrey et al. [31]	APC humerus (6), ulna (18 cases), both (1). APC types I-III	25	60	3.4 years	84	Bone incorporation 92%	9 reoperations in 6 patients Resection arthroplasty in 4 cases 3 infections, 3 fractures, 1 nonunion, 1 malunion, 1 skin necrosis, 1 triceps insufficiency and 1 ulnar nerve paresthesia

N number, *MEPS* Mayo Elbow Performance score, *NA* nonavailable

In a review of the most recent experience, Morrey et al. reported on 25 patients that underwent an APC of the humerus (6 cases), the ulna (18 cases), or both (1 case) [31]. The existence of an extended flange in the humeral component can explain the use of fewer APCs in the humerus that can compensate a bone loss of approximately 8 cm. The indications were aseptic implant loosening with a fracture or cortical defect (11) or without fracture (3), infection (7), failed implants (1), bone loss after hemiarthroplasty (1), nonunion (1), and resection arthroplasty (1). The APC was used in three ways, being intussuscepted into the remaining proximal ulna in cases where the cortical bone was expanded or a small cortical defect was found. In cases of a significant cortical defect at the implant insertion site, the use of a strut-like coaptation APC was used. The implant was stabilized into the allograft, but the stem emerges from the allograft to fit into the host ulna while a strut from the APC can coapt externally with the host bone. In cases of insufficient bone and malalignment, the APC was fixed in a side-to-side manner with wires. The diameter of the wires was larger for the humerus. For these cases, the stem was cemented (with antibiotics) into the allograft, and then the composite was fixed to the host. In type I and II fractures, the cement could be applied after the implant was introduced into the canal, the reason for this being adequate reproduction of arm length and soft tissue tension. The authors reported improved MEPS of 54 points (84 points at last follow-up) with incorporation of the allograft in 92%. There were three infections, three fractures, one nonunion, one malunion, one skin necrosis, one triceps insufficiency, and one ulnar nerve paresthesia. There were nine reoperations in six patients, resection arthroplasty being done in four cases.

Amiyfeiz et al. reported on similar outcomes for 10 patients (11 elbows) with a mean age of 64 years that underwent 14 APC reconstructions for massive structural bone loss [30]. At 75 months follow-up, patients achieved a functional arc of motion and an improvement of the MEPS from 9.9 preoperatively to 74 points postoperatively. The authors observed partial resorption in 50% of their grafts, but the humeral grafts showed healing in one of eight while the ulnar grafts had increased rates of healing (seven of eight), which prompted them to counsel regular long-term review of these patients.

12.7 The Infected TEA

The rate of infection is variable with a median of 3.3% and ranges from 0 to 11% [32–34].The infected TEA poses its specific set of problems. While the success of one-stage revision has been around 85% in the lower limb, it is decreased in TEA. The factors for this are not well known but may include the common existence of prior procedures and the thin, soft tissue sleeve around the elbow.

There are four approaches to treatment, including resection arthroplasty, implant retention and debridement, and one- and two-stage revisions (Table 12.7) [25, 35–40]. Fusion is difficult to achieve in these situations and results in poor function. The decision of which technique to perform is based on the health status of the patient, the timing of the infection, the type of organism, and the existence of loose components and bone loss. Typically, two-stage revisions are the preferred treatment for chronic infections, compromised soft-tissue, or with the presence of a sinus tract.

Resection arthroplasty is considered for patients without the desire or status to undergo additional procedures, massive bone loss, and a highly resistant organism. It is interesting to note that patients did still benefit from the operation with an improvement of function from 37 to 60 points (MEPS) [38].

Implant retention and debridement is an attractive option to decrease the complications of implant removal at the cost of a risk of undergoing successive debridement procedures. The rate of infection control ranges from 50% to 80% in modern literature and is an effective strategy if the implants are well fixed and the organism is sensitive to treatment.

Spormann et al. reported on eight cases with early infection and ten cases of late presentation

Table 12.7 Results of the infected total elbow arthroplasty (TEA) depending on the treatment strategy

Author	Patients (*N*)	Age at surgery	Follow-up (months)	Procedure	Infection control	Complications/observations
Morrey [35]	14	52	20	Resection (10) Debridement (1) reimplantation (2) Amputation (1)	APC removed in 3 2 nonunions of the graft	Both reimplantations had good results. 7/10 resection arthroplasties had no pain
Wolfe et al. [36]	14	50	4.1 years	Initial debridement + ATB (12). Final treatment included: Resection (7), debridement (4), arthrodesis (2), reimplantation (1)	8 out of 12 had recurrent infections after debridement. 50% retained implants—intermittent drainage	5 of 7 resections did poorly
Yamaguchi et al. [37]	25	58	71	DAIR (14), resection, debridement and staged reimplantation (6), Resection (5)	Debridement 50% success 2/6 recurrent infection after reimplantation No recurrence after resection arthroplasty	Low-virulence microorganisms (*S. epidermidis*) had poor results
Zarkadas PC et al. [38]	29 (30 elbows)	59	11 years	Resection arthroplasty	100%	MEPS 60, DASH 71 Complications (reported from the original cohort of 50 patients): intraoperative fractures (18), wound healing problems (12), permanent nerve injury (9), additional surgeries for soft tissue healing
Peach CA et al. [40]	33 (34 elbows)	65	NA	2-stage procedure with ATB-laden beads. A second stage was performed in 26 (76%)	11.5%	Triceps weakness (1), periprosthetic ulna fracture (1)
Rhee YG et al. [25]	9 (10 elbows)	52	NA	Resection arthroplasty	100%	MEPS 73.5, DASH 53 Better results if they had both columns. Satisfaction 70% Additional operation in 1 case
Streubel et al. [39]	23	58	7.1 years	Unlinking, irrigation and debridement (I&D), + ATB- cement beads + iv ATB organism-specific; repeat I&D and relinkage of the implant if infection control; long-term oral antibiotic therapy	90% implant survival *S. aureus* 9 *S. coagulase*–negative 13 *Corynebacterium* 3 Others in 6	Mean MEPS 78 G/E results in 15/22 8 patients needed reoperations: 3 repeat Staged I + D 2 repeat superficial I + D 1 forearm flap 1 TEA removed for persistent infection

N number, *APC* allograft-prosthetic composite, *ATB* antibiotic, *DAIR* debridement and retention of the implant, *MEPS* Mayo Elbow Performance score, *DASH* disabilities of the arm hand and shoulder, *I&D* irrigation and debridement, *G/E* good and excellent results

(2 years after index procedure) treated with debridement and irrigation [41]. Repeat irrigation was performed one week after if the inflammatory markers were not back to baseline values. All cases of early infection were successful while only three of ten late presentations were controlled. These patients had a duration of symptoms of less than 10 days. Streubel et al. using a similar protocol achieved 81% success with a satisfactory functional outcome in 75% of patients [39].

In both previous studies the presence of infection by *S. epidermidis* precluded successful treatment with debridement alone and should be managed with a different strategy.

Revision of the implant is typically performed in two stages. Gille et al. performed a single-stage revision in six patients with two of them recurring in the first 6 months [42]. The two-stage revision is considered the standard of care in periprosthetic joint infection, but compared to the hip literature, the success rate is diminished. In a group of revision procedures Cheung et al. reported on 29 elbows with a two-stage protocol that included 6-week course of i.v. ATB and reimplantation if inflammatory markers were normalized [43]. During the second stage procedure, at least three biopsies had to demonstrate the absence of inflammation to continue. They reported a success rate of 72% with a survival-free of reoperation rate at 3 years of 77%. Eight elbows had a recurrent infection, and they underwent resection arthroplasty. The functional outcome in those with a retained implant was poor in only three patients (14%).

Peach et al. reviewed 26 patients undergoing resection and antibiotic-laden cement beads and reimplantation with a success rate of 88.5%. Patients without recurrence had mean MEPS of 81.1 points at 2-years follow-up. Of note, 24% of the patients did not undergo the second stage of revision [40]. *S. coagulase*–negative organisms caused the majority of infections.

All authors use inflammatory markers for diagnosis and to monitor the postoperative follow-up and delay the second stage at least until these markers had recovered baseline values [44]. However, the thresholds are not clear, specifically in patients with inflammatory arthritis. The role of aspiration is controversial, but many authors have used it to try to guide antibiotic treatment despite the universal role of intraoperative tissue culturing and antibiotic sensibility testing. The use of antibiotic-laden cement is widespread despite the lack of evidence in the elbow, but it is based on extrapolated data from other joints and all attempts are made to remove all foreign material from the canals although this has to be weighed against the effort to remove bone stock. Despite all these efforts, some patients will have positive cultures after the second stage implantation. These patients are candidates for long-term suppressive antibiotics or resection arthroplasty depending on the type and sensitivity of the organism.

12.8 Conclusions

Revision total elbow arthroplasty (TEA) is a complex treatment for the patient and treating physician. It is essential to analyze the reason for failure so as not to repeat the same mistake. In consequence, it may have implications on the design of the prostheses or technical aspects with regards to implantation technique, cementing, or implant positioning. The presence of bone loss increases the complexity and risk of failure. As such all efforts must be made to increase the available bone stock. The presence of infection can further complicate all the technical issues. Periprosthetic joint infection is hard to diagnose and typically requires more than one operation. Coordination with an infection specialist may be beneficial for the patient. The rate of periprosthetic fractures only increases with longer-term follow-up and may require strut grafting. Revision surgery requires attention to detail, an important team effort involving different specialists and is technically demanding. As such, it may be appropriate to transfer the patient to an institution that has all the necessary resources and experience for the treatment of these kinds of patients.

References

1. Klug A, Gramlich Y, Buckup J, Schweigkofler U, Hoffmann R, Schmidt-Horlohe K. Trends in total elbow arthroplasty: a nationwide analysis in Germany from 2005 to 2014. Int Orthop. 2018;42:883–9.
2. Perretta D, van Leeuwen WF, Dyer G, Ring D, Chen N. Risk factors for reoperation after total elbow arthroplasty. J Shoulder Elb Surg. 2017;26:824–9.
3. Krukhaug Y, Hallan G, Dybvik E, Lie SA, Furnes ON. A survivorship study of 838 total elbow replacements: a report from the Norwegian Arthroplasty Register 1994-2016. J Shoulder Elb Surg. 2018;27:260–9.
4. Krenek L, Farng E, Zingmond D, SooHoo NF. Complication and revision rates following total elbow arthroplasty. J Hand Surg. 2011;36:68–73.
5. Lovy AJ, Keswani A, Dowdell J, Koehler S, Kim J, Hausman MR. Outcomes, complications, utilization trends, and risk factors for primary and revision total elbow replacement. J Shoulder Elb Surg. 2016;25:1020–6.
6. Barco R, Streubel PN, Morrey BF, Sanchez-Sotelo J. Total elbow arthroplasty for distal humeral fractures: a ten-year-minimum follow-up study. J Bone Joint Surg Am. 2017;99:1524–31.
7. Sanchez-Sotelo J, O'Driscoll S, Morrey BF. Periprosthetic humeral fractures after total elbow arthroplasty: treatment with implant revision and strut allograft augmentation. J Bone Joint Surg Am. 2002;84:1642–50.
8. Geurts EJ, Viveen J, van Riet RP, Kodde IF, Eygendaal D. Outcomes after revision total elbow arthroplasty: a systematic review. J Shoulder Elb Surg. 2019;28:381–6.
9. Sneftrup SB, Jensen SL, Johannsen HV, Søjbjerg JO. Revision of failed total elbow arthroplasty with use of a linked implant. J Bone Joint Surg Br. 2006;88:78–83.
10. Shi LL, Zurakowski D, Jones DG, Koris MJ, Thornhill TS. Semiconstrained primary and revision total elbow arthroplasty with use of the Coonrad-Morrey prosthesis. J Bone Joint Surg Am. 2007;89:1467–75.
11. Malone AA, Sanchez JS, Adams R, Morrey B. Revision of total elbow replacement by exchange cementing. J Bone Joint Surg Br. 2012;94:80–5.
12. Day JS, Baxter RM, Ramsey ML, Morrey BF, Connor PM, Kurtz SM, et al. Characterization of wear debris in total elbow arthroplasty. J Shoulder Elb Surg. 2013;22:924–31.
13. Baghdadi YM, Jacobson JA, Duquin TR, Larson DR, Morrey BF, Sanchez-Sotelo J. The outcome of total elbow arthroplasty in juvenile idiopathic arthritis (juvenile rheumatoid arthritis) patients. J Shoulder Elb Surg. 2014;23:1374–80.
14. Sanchez-Sotelo J, Baghdadi YM, Morrey BF. Primary linked semiconstrained total elbow arthroplasty for rheumatoid arthritis: a single-institution experience with 461 elbows over three decades. J Bone Joint Surg Am. 2016;98:1741–8.
15. Griffin JW, Werner BC, Gwathmey FW, Chhabra AB. Obesity is associated with increased postoperative complications after total elbow arthroplasty. J Shoulder Elb Surg. 2015;24:1594–601.
16. Morrey ME, Hevesi M. The influence of obesity on total elbow arthroplasty. Orthop Clin North Am. 2018;49:361–70.
17. Ramirez MA, Cheung EV, Murthi AM. Revision total elbow arthroplasty. J Am Acad Orthop Surg. 2017;25:e166–e74.
18. Kho JY, Adams BD, O'Rourke H. Outcome of semiconstrained total elbow arthroplasty in posttraumatic conditions with analysis of bushing wear on stress radiographs. Iowa Orthop J. 2015;35:124–9.
19. Wright TW, Hastings H. Total elbow arthroplasty failure due to overuse, C-ring failure, and/or bushing wear. J Shoulder Elb Surg. 2005;14:65–72.
20. Lee BP, Adams RA, Morrey BF. Polyethylene wear after total elbow arthroplasty. J Bone Joint Surg Am. 2005;87:1080–7.
21. Mansat P, Bonnevialle N, Rongières M, Mansat M, Bonnevialle P, French Society for Shoulder and Elbow SOFEC. Results with a minimum of 10 years follow-up of the Coonrad/Morrey total elbow arthroplasty. Orthop Traumatol Surg Res. 2013;99(6 Suppl):S337–43.
22. Athwal GS, Morrey BF. Revision total elbow arthroplasty for prosthetic fractures. J Bone Joint Surg Am. 2006;88:2017–26.
23. Ehrendorfer S. Elbow revision arthroplasty in the situation of bone loss using an unlinked long-stem prosthesis. J Hand Surg. 1999;24:1337–43.
24. Loebenberg MI, Adams R, O'Driscoll SW, Morrey BF. Impaction grafting in revision total elbow arthroplasty. J Bone Joint Surg Am. 2005;87:99–106.
25. Rhee YG, Cho NS, Parke CS. Impaction grafting in revision total elbow arthroplasty due to aseptic loosening and bone loss. J Bone Joint Surg Am. 2013;95:e741–7.
26. Kamineni S, Morrey BF. Proximal ulnar reconstruction with strut allograft in revision total elbow arthroplasty. J Bone Joint Surg Am. 2004;86:1223–9.
27. Moro F. Allograft reconstruction in revision elbow arthroplasty. Der Orthopade. 2017;46:1001–7.
28. Foruria AM, Sanchez-Sotelo J, Oh LS, Adams RA, Morrey BF. The surgical treatment of periprosthetic elbow fractures around the ulnar stem following semiconstrained total elbow arthroplasty. J Bone Joint Surg Am. 2011;93:1399–407.
29. Tokunaga D, Hojo T, Ohashi S, Hirata M, Tokumoto Y, Nagashima S, et al. Periprosthetic ulnar fracture after loosening of total elbow arthroplasty treated by two-stage implant revision: a case report. J Shoulder Elb Surg. 2006;15:e23–6.
30. Amirfeyz R, Stanley D. Allograft-prosthesis composite reconstruction for the management of failed elbow replacement with massive structural bone loss:

a medium-term follow-up. J Bone Joint Surg Br. 2011;93(10):1382–8.
31. Morrey ME, Sanchez-Sotelo J, Abdel MP, Morrey BF. Allograft-prosthetic composite reconstruction for massive bone loss including catastrophic failure in total elbow arthroplasty. J Bone Joint Surg Am. 2013;95:1117–24.
32. Somerson JS, Boylan MR, Hug KT, Naziri Q, Paulino CB, Huang JI. Risk factors associated with periprosthetic joint infection after total elbow arthroplasty. Shoulder Elbow. 2019;11:116–20.
33. Kasten MD, Skinner HB. Total elbow arthroplasty. An 18-year experience. Clin Orthop Relat Res. 1993;290:177–88.
34. Aldridge JM 3rd, Lightdale NR, Mallon WJ, Coonrad RW. Total elbow arthroplasty with the Coonrad/Coonrad-Morrey prosthesis. A 10- to 31-year survival analysis. J Bone Joint Surg Br. 2006;88:509–14.
35. Morrey BF, Bryan RS. Infection after total elbow arthroplasty. J Bone Joint Surg Am. 1983;65:330–8.
36. Wolfe SW, Figgie MP, Inglis AE, Bohn WW, Ranawat CS. Management of infection about total elbow prostheses. J Bone Joint Surg Am. 1990;72:198–212.
37. Yamaguchi K, Adams RA, Morrey BF. Infection after total elbow arthroplasty. J Bone Joint Surg Am. 1998;80:481–91.
38. Zarkadas PC, Cass B, Throckmorton T, Adams R, Sanchez-Sotelo J, Morrey BF. Long-term outcome of resection arthroplasty for the failed total elbow arthroplasty. J Bone Joint Surg Am. 2010;92:2576–82.
39. Streubel PN, Simone JP, Morrey BF, Sanchez-Sotelo J, Morrey ME. Infection in total elbow arthroplasty with stable components: outcomes of a staged surgical protocol with retention of the components. Bone Joint J. 2016;98-B:976–83.
40. Peach CA, Nicoletti S, Lawrence TM, Stanley D. Two-stage revision for the treatment of the infected total elbow arthroplasty. Bone Joint J. 2013;95-B:1681–6.
41. Spormann C, Achermann Y, Simmen BR, Schwyzer HK, Vogt M, Goldhahn J, et al. Treatment strategies for periprosthetic infections after primary elbow arthroplasty. J Shoulder Elb Surg. 2012;21:992–1000.
42. Gille J, Ince A, Gonzalez O, Katzer A, Loehr JF. Single-stage revision of peri-prosthetic infection following total elbow replacement. J Bone Joint Surg Br. 2006;88:1341–6.
43. Cheung EV, Adams RA, Morrey BF. Reimplantation of a total elbow prosthesis following resection arthroplasty for infection. J Bone Joint Surg Am. 2008;90:589–94.
44. Somerson JS, Morrey ME, Sanchez-Sotelo J, Morrey BF. Diagnosis and management of periprosthetic elbow infection. J Bone Joint Surg Am. 2015;97:1962–71.

13 Revision Total Ankle Arthroplasty: Epidemiology and Causes

E. Carlos Rodríguez-Merchán
and Inmaculada Moracia-Ochagavía

13.1 Introduction

Total ankle arthroplasty (TAA) was initially popularized in the 1970s as an alternative to tibiotalar fusion for advanced tibiotalar osteoarthritis; however, failures were serious. Contemporary designs show promise, focusing on normal joint anatomy and function with greatly improved materials and a more accurate surgical technique. However, even with advancements in technology and implant engineering, implant failure remains a problem [1].

According to Myerson et al., the chief indications for revision TAA (RTAA) include loosening and subsidence of the talar component with no limit to the extent of subsidence or loss of talar bone stock, given neither prevents use of a revision system, especially when a flat cut on the talus can be made [2].

Roukis and Elliot reported a systematic review to recognize the material relating to the frequency of revision after implantation of the Salto mobile version and Salto-Talaris TAAs [3]. Forty-eight patients with Salto mobile version prostheses (4%) went through revision of whom 24 (70.5%) were subjected to tibiotalar fusion, 9 (26.5%) to metallic component replacement, and 1 (3%) to below-the-knee amputation. Five (2.4%) Salto-Talaris TAAs went through revision (three metallic component replacements and two tibiotalar arthrodeses). Restricting the data to the inventor, design team, or disclosed consultants, the frequency of revision was 5.2% for the Salto mobile version and 2.6% for the Salto-Talaris TAAs. In contrast, data that excluded these individuals had a rate of revision of 2.8% for the Salto mobile version and 2.0% for the Salto-Talaris TAAs. Roukis and Elliott could not determine any clear difference in the etiology responsible for the rate of revision between these mobile- and fixed-bearing designs. The rates of revision for the Salto mobile version and Salto-Talaris TAAs were lower than those reported for the Agility and STAR (Swedish Total Ankle Replacement) designs without apparent selection (inventor) or publication (conflict of interest) bias. The purpose of this chapter is to analyze the epidemiology and causes of RTAA.

13.2 Epidemiology

A systematic review reported in 2013 by Prissel and Roukis analyzed the rates of failure and revision of the STAR design, showing a 10.7% revision rate at weighted mean follow-up of 64 months [1].

In 2013, Labek et al. analyzed several national arthroplasty registers worldwide (Sweden,

E. C. Rodríguez-Merchán (✉)
I. Moracia-Ochagavía
Department of Orthopedic Surgery, "La Paz" University Hospital, Madrid, Spain

E. C. Rodríguez-Merchán (ed.), *Revision Total Joint Arthroplasty*,
https://doi.org/10.1007/978-3-030-24773-7_13

Finland, Norway, New Zealand, and Australia) [4]. They found that the outcomes of TAA were promising, but the revision rate was higher than for total hip or knee arthroplasty. They also found differences between Europe and Oceania with respect to indications. All registers showed revision rates of approximately 10% at 5 years of which about 40% of cases were for aseptic loosening. Inlay fractures were relatively frequent, which indicated a potential for an improved design. The causes of intraoperative surgical errors leading to RTAA varied significantly among registers.

In 2013, Noelle et al. analyzed 114 STAR prostheses implanted over a 6-year period (2005–2010). The average follow-up was 36 months. The reported revision rate was 14.9% [5]. A total of 87% of the patients reported a better quality of life. Twenty-seven (27/114) ankles had complications after primary surgery, and 21 prostheses (21/114) needed revision surgery, including 4 patients who required tibiotalar fusion. This study showed a high satisfaction rate after TAA and clear pain relief. Patients with body mass index (BMI) higher than 30 showed a higher rate of complications. Compared with tibiotalar fusion, the complication rates were similar.

In 2018, Lai et al. studied the rate and predictors of early complications after primary and RTAA. In a 7-year period (2010–2016), 905 patients were studied, of whom 818 went through primary TAA (90.4%) and 87 through experienced RTAA (9.6%) [6]. The overall complication rate was 5.5% (50/905). Complications occurred more commonly after RTAA (9/87) than following primary TAA (41/818). Age, BMI, and RTAA were independent risk factors for 30-day complications.

Law et al. analyzed the trends in TAA use and the rate of RTAA using the Medicare database [7]. Their analysis showed that there was a high rate of yearly growth in TAA use (16.37%) and RTAA (7.74%), indicating an increased demand for TAA in the Unites States. However, they concluded that failed TAA can have perilous repercussions, and RTAA continues to have suboptimal outcomes. Table 13.1 summarizes the rates of RTAA found in the literature (2–15%).

Table 13.1 Rates of revision total ankle arthroplasty (TAA) in the literature

Author	Year	Design	Rate	Comments
Prissel and Roukis [1]	2013	STAR	10.7%	No comments
Labek et al. [4]	2013	Multiple designs	10% (40% for aseptic loosening)	Registry data from Sweden, Finland, Norway, New Zealand, and Australia were included in this analysis
Noelle et al. [5]	2013	STAR	14.9%	No comments
Roukis and Elliott [3]	2015	Salto mobile and Salto-Talaris	From 2.6% to 5.2% (Salto mobile); from 2% to 2.8% (Salto-Talaris)	Restricting the data to the inventor, design team, or disclosed consultants, the incidence of revision was 5.2% for the Salto mobile version and 2.6% for the Salto-Talaris TAAs. In contrast, data that excluded these individuals had an incidence of revision of 2.8% for the Salto mobile version and 2% for the Salto-Talaris TAAs. The incidences of revision for the Salto mobile version and Salto-Talaris TAAs were lower than those reported through systematic review for the Agility and STAR systems without obvious selection (inventor) or publication (conflict of interest) bias
Lai et al. [6]	2015	NA	9.6%	No comments
Law et al. [7]	2018	NA	7.74%	Medicare database

STAR Swedish Total Ankle Replacement, *NA* nonavailable

13.3 Causes and Risk Factors

In a series of 114 TAAs (STAR prostheses) reported in 2013 by Noelle et al., 27 (27/114, 23.6%) ankles had complications following primary surgery, and 21 prostheses (21/114, 18.4%) needed revision surgery (14.9% revision TAA), including 4 (3.5%) patients who required tibiotalar fusion. Patients with BMI > 30 showed a higher rate of complications [5].

In 2014, Sadoghi et al. studied the modes of failure after TAA (Table 13.2) (Figs. 13.1, 13.2 and 13.3). They emphasized the importance of comprehending the most frequent failure modes of TAA to suitably designate the resources, healthcare costs, improve surgical treatment methods, and improve the design and longevity of the prostheses [8]. They did not find significant differences between any of the failure modes. However, they found that the number of TAAs was increasing with time.

In 2015, Horisberger et al. reported that bone augmentation was required for RTAA with large osseous defects. In a 5-year period, 10 patients with aseptic loosening of TAA associated with great bone loss at the tibia, the talus, or both, were treated. Autologous structural iliac crest bone augmentation, as a one- or two-stage approach, was used [9]. Adequate bone stock was successfully reestablished. At an average follow-up of 4 years, 2 of 10 cases had to be converted to tibiotalocalcaneal fusion due to persistent pain with considerable arthrofibrosis (joint stiffness) but not loosening.

Patton et al. analyzed the risk factors for infected TAA in a retrospective comparative study (level III of evidence). A group of 966

Table 13.2 Main modes of failure of total ankle arthroplasty (TAA)

Loose talar components
Loose tibial component
Dislocation
Instability
Malalignment (Fig. 13.1)
Deep infection
Fracture (near implant) (Fig. 13.2)
Pain
Defective polyethylene

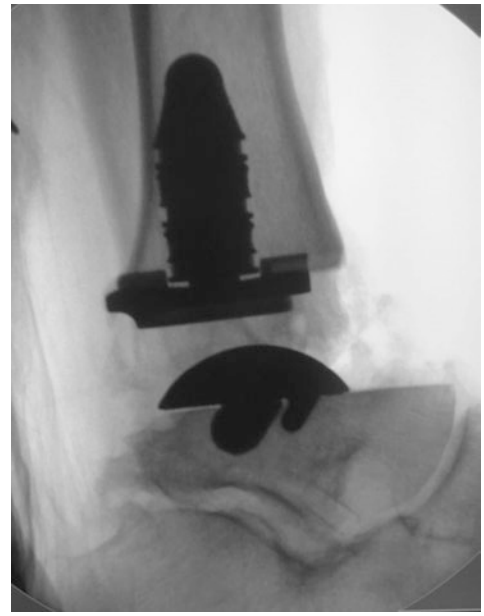

Fig. 13.1 Intraoperative fluoroscopic image in which an incorrect implantation of the tibial stem can be observed in an Inbone II total ankle prosthesis. The stem provides diaphyseal support to the prosthesis but can increase the risk of sagging of the tibial plate due to the lack of coverage of the anterior cortex of the tibia

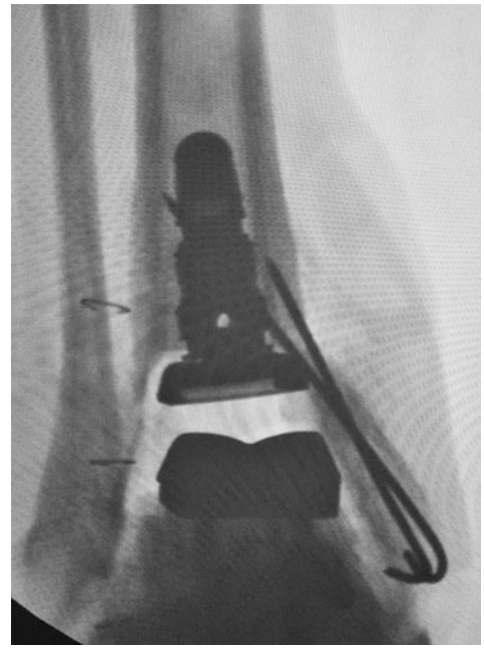

Fig. 13.2 Intraoperative fluoroscopy image. A fracture of the tibial malleolus has occurred during prosthetic implantation, and an osteosynthesis with percutaneous K wires has been performed

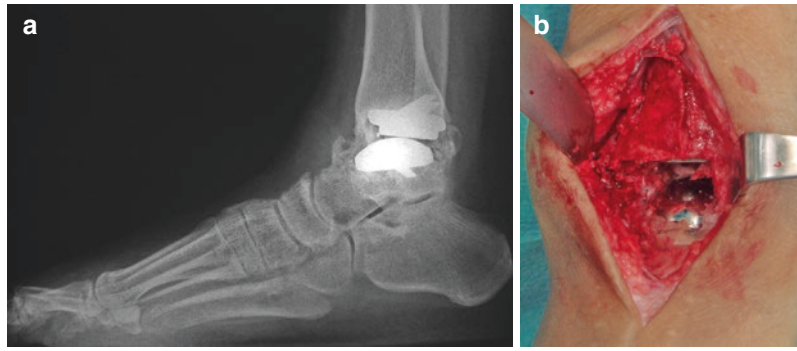

Fig. 13.3 A 70-year-old patient with joint pain and stiffness after Ramses ankle prosthesis. (**a**) On the lateral ankle radiograph, loosening can be observed with sinking of the talar and tibial components with the presence of anterior and posterior heterotopic ossification. (**b**) Intraoperative image after debridement and resection of the heterotopic ossification in which the subsidence of both components (talar and tibial) can be observed

patients with TAA were reviewed, and 29 cases of infected TAA (3.2%) were identified. The rate of infection in primary TAA was 2.4%, and in RTAA it was 4%. Risk factors for infection in this study included diabetes, previous ankle surgery, and wound healing problems more than 14 days postoperatively. No significant difference was found between groups with respect to risk factors such as smoking, BMI, and operative time [10]. These authors concluded that given the morbidity of infected TAA, meticulous consideration should be made about performing TAA in patients with multiple previous surgeries and comorbidities that predispose to wound-healing difficulties.

In a prospective comparative study (level II of evidence) reported in 2015, Demetracopoulos et al. found that the outcomes of TAA in younger patients were similar to the outcomes in older patients at early follow-up. Some 395 patients were reviewed with a mean follow-up of 3.5 years (range, 2–5.4 years). Patients were divided into three groups based on age at the time of surgery (<55, 55–70, and > 70 years). The rate of wound complications, need for reoperation, and revision were comparable between groups [11].

Roukis and Elliot could not identify any obvious difference in the reasons for revision between the Salto mobile and the Salto-Talaris (fixed-bearing) prostheses. However, the incidence of revision for the Salto mobile version and Salto-Talaris TAAs was lower than that reported for the

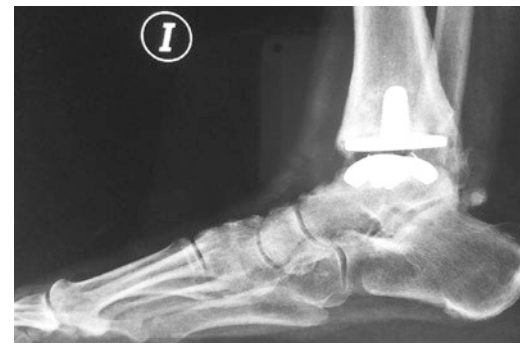

Fig. 13.4 Patient with pain and instability in the ankle 3 years after the implantation of a Mobility total ankle prosthesis. Lateral radiograph shows a radiolucent line greater than 2 mm around the tibial stem and loosening and sinking of the talar component

Agility and STAR systems without obvious selection (inventor) or publication (conflict of interest) bias [3].

Steck et al. reported in 2017 that factors such as patient selection, surgeon experience, implant features, and prosthetic device selection could affect functional results as well as the rate of complications after RTAA (Fig. 13.4). Thus, even with faultless surgical technique and optimal patient selection, complications that require revision can still arise [12].

In 2017, Di Iorio et al. reported a prospective case series (level IV of evidence) on the Ankle Evolutive System (AES, a mobile-bearing TAA evolved from the Buechel Pappas model)

TAA. The overall 10-year survival was lower than with other prostheses, especially due to cyst lesions. Fifty AES prostheses were analyzed. Preoperative osteoarthritis was largely posttraumatic (50%) and secondary to instability (36%). The mean follow-up was 10 years (range, 9–13) [13]. Fifteen patients with TAAs went through reoperation for cyst curettage graft because of development of periprosthetic lesions, six of who ended up with prosthesis removal for fusion. At the most recent follow-up, 14 TAAs were removed for fusion. Of the 30 prostheses seen at the most recent follow-up, 4 were awaiting prosthesis removal for fusion and 1 for cyst curettage graft. The 10-year survivorship free of any prosthesis removal or tibiotalar fusion and free of any reoperation was 68% and 57%, respectively.

According to Elliot and Roukis, delayed wound healing of the anterior incision is frequent after primary and RTAA surgery [14]. These authors have been using a modified Sir Robert Jones compressive dressing for both primary and revision TAAs. They have added an aperture pad made of cotton cast padding over the anterior incision to protect the area from pressure necrosis. They performed a comparison study of the postoperative wound complications involving 35 patients who received the original dressing and 33 patients who received the addition of the aperture pad. With no significant difference in the patient populations, the outcomes showed a three-fold reduction in the number of anterior incision wound healing complications with the use of the aperture pad. Elliott and Roukis concluded that the dressing they used represented a simple, reproducible, easy to apply and inexpensive way to avoid postoperative edema and anterior incision wound healing complications.

Periprosthetic joint infection (PJI) after TAA is a serious complication that frequently requires removal to resolve the infection. In 2018, Althoff et al. attempted to determine the patient-related risk factors of PJI following TAA. A national insurance database was queried for patients undergoing TAA using the Current Procedural Terminology and International Classification of Diseases, ninth revision, procedure codes from 2005 to 2012 [15]. A multivariate binomial logistic regression analysis was performed to assess the patient-related risk factors for PJI. A total of 6977 patients were included in the study. Of these 6977 patients, 294 (4%) had a diagnosis of PJI or had been subjected to a procedure for it. The independent risk factors for PJI included age < 65 years, BMI <19, BMI >30, tobacco use, diabetes mellitus, inflammatory arthritis, peripheral vascular disease, chronic lung disease, and hypothyroidism.

Sansosti et al. studied the effect of obesity on TAA [16]. They performed a review of electronic databases with the inclusion criteria of retrospective case series, retrospective clinical cohort analyses, and prospective clinical trials with ≥15 total patients, a mean follow-up period of ≥12 months, ≥1 defined cohort with a BMI of ≥30, and a reported incidence rate of complications requiring revisional surgery at the final follow-up point. Four studies met the inclusion criteria, where a total of 400 prostheses were analyzed. Of these, ≥71 (17.8%) developed a complication needing a revisional surgical procedure. The most frequently reported surgeries were revision of the metallic components and ankle gutter debridement.

In 2018, Gramlich et al. reported that TAA leads to high revision rates in posttraumatic end-stage osteoarthritis [17]. In a 6-year period (2008–2013), 74 patients with posttraumatic osteoarthritis were treated using TAA with a Tornier Salto prosthesis, and 60 (35 men and 25 women; mean age 56) were followed-up (mean: 59 months; range 24–91 months). The revision rate after TAA was 42% ($n = 25$), amounting to 8% after 12 months and 18% after 24 months. Twenty percent of the patients had symptomatic periprosthetic bone cysts, 5% had impingement, 3% had soft tissue infections, and in 14% of the cases revision was caused by other factors. The most frequently performed procedures were cyst debridement and autologous spongy bone grafting (20%). Fifteen percent ($n = 9$) of the prosthetics were explanted or switched to a tibiotalar fusion. The main conclusion was that TAA in patients with posttraumatic end-stage arthrosis is associated with high revision rates. High rates of symptomatic periprosthetic bone cysts caused

high rates of revision surgery and poorer results, which were not ameliorated by secondary TAA.

In a case series (level IV of evidence), Cody et al. found an increased early revision rate with the two-component Infinity TAA [18]. They analyzed 159 ankles with a mean 20 months of follow-up (range, 12–37). All surgeries were performed by one of two orthopedic foot and ankle surgeons with extensive experience in TAA. The primary outcome was the need for revision surgery, defined as removal of one or both metal components. Periimplant lucency at the most recent follow-up was a secondary outcome. Weight-bearing radiographs at the most recent follow-up were graded for lucency independently by two reviewers. Sixteen (10%) ankles went through revision at a mean 13 months postoperatively. The most frequent reasons for revision were symptomatic tibial component loosening and deep infection (6 patients each, 3.8%). Of the 108 ankles with retained components and at least 1 year of radiographic follow-up, 8 (7.4%) had global lucency around the tibial component suggestive of loosening at the most recent follow-up. This study on patients experiencing TAA with the two-component Infinity prosthesis showed an elevated early revision rate due to tibial component loosening compared with other implant systems.

In a 17-year (2002–2018) comparative study (level III of evidence), Currier et al. analyzed 70 failed TAA components (7 designs, including 5 currently marketed designs) that required revision [19]. The implants were retrieved most commonly due to loosening and polyethylene fracture. Loosening happened more often in fixed-bearing designs ($n = 18$) than in the mobile-bearing designs ($n = 4$) and after shorter in vivo time (mean in vivo time to retrieval for loosening: fixed bearing 3.2 years, mobile bearing 9.7 years). Gamma-sterilized ankle inserts oxidized at a higher rate than nongamma (EtO or gas-plasma) sterilized ankle inserts (gamma 0.29/year, nongamma 0.07/year). The presence of clinical fatigue (cracking and/or delamination) of the polyethylene insert correlated with measured oxidation. Nine inserts, all gamma-sterilized, fractured in vivo. This report suggested that loosening could be more of a problem in fixed-bearing deigns than in mobile-bearing designs. Gamma-sterilized polyethylene inserts were found to suffer fatigue damage or fracture in vivo, resulting in the need for revision. Figure 13.5 shows the intraoperative view of a RTAA case. Note the existence of marked metallosis and great loss of bone stock before performing debridement and cleaning of debris.

In a retrospective cohort study (level III of evidence), Cody et al. studied the risk factors for failure of TAA with a minimum 5 years of follow-up. They analyzed 533 ankles with a mean 7 (range, 5–11) years of follow-up. Four implants were used: INBONE I, INBONE II, STAR, and Salto-Talaris [20]. Thirty-four ankles (6.4%) were revised or removed a mean 4 (range, 1–9) years postoperatively. The only independent predictors of failure were the INBONE I prosthesis

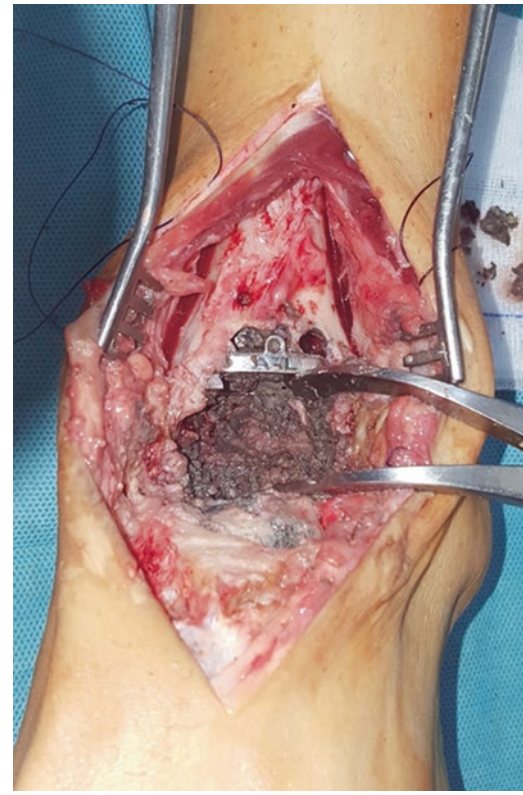

Fig. 13.5 Intraoperative image of prosthetic revision surgery of the ankle showing intense metallosis and great loss of bone stock before debridement and debris cleansing

Table 13.3 Main risk factors (causes) for revision total ankle arthroplasty (RTAA)

Inadequate patient selection
Poor surgeon experience
Obesity (BMI >30)
Posttraumatic and end-stage osteoarthritis (high revision rates in posttraumatic end-stage osteoarthritis)
Poor restoration of bone stock
Inadequate prosthetic device selection (poor implant features): • Loosening occurs more frequently in fixed-bearing designs than in the mobile-bearing designs • Gamma-sterilized polyethylene inserts suffer fatigue damage or fracture in vivo, resulting in the need for revision • Salto mobile higher rate of revision than Salto-Talaris; however, the incidences of revision for the Salto mobile version and Salto-Talaris TAAs were lower than those reported through systematic review for the Agility and STAR systems without obvious selection (inventor) or publication (conflict of interest) bias • AES TAA. Overall 10-year survival was lower than with other designs, particularly due to cyst lesions • Increased early revision rate with the two-component Infinity has been reported • INBONE I prosthesis is at significantly higher risk of implant failure than INBONE II, STAR, and Salto-Talaris
Inadequate control of risk factors for periprosthetic joint infection (PJI): Age < 65 years, BMI <19, BMI >30, tobacco use, diabetes mellitus, inflammatory arthritis, peripheral vascular disease, chronic lung disease, hypothyroidism, prior ankle surgery, and wound healing problems more than 14 days postoperatively
Ipsilateral hindfoot fusion is at significantly higher risk of implant failure

AES ankle evolutive system (mobile-bearing TAA evolved from the Buechel Pappas model), *TAA* total ankle arthroplasty *BMI* body mass index

and ipsilateral hindfoot fusion. Age, BMI, and the amount of deformity were not associated with higher failure rates. Only patients with ipsilateral hindfoot fusion or who received the INBONE I prosthesis were at a higher risk of implant failure. Table 13.3 summarizes the main risk factors (causes) for RTAA.

13.4 Conclusions

The reported rates of revision after TAA range from approximately 2.5% to around 15%. The primary modes of failure are loose talar component, loose tibial component, dislocation, instability, misalignment, deep infection, fracture (near implant), pain, and defective polyethylene. The main risk factors for RTAA are inadequate patient selection, poor surgeon experience, obesity (BMI >30), posttraumatic and end-stage osteoarthritis, poor restoration of bone stock, inadequate prosthetic device selection (poor implant features), inadequate control of risk factors for PJI (age < 65 years, BMI <19, BMI >30, tobacco use, diabetes mellitus, inflammatory arthritis, peripheral vascular disease, chronic lung disease, hypothyroidism, previous ankle surgery, wound healing problems more than 14 days postoperatively, and ipsilateral hindfoot fusion.

References

1. Prissel MA, Roukis TS. Incidence of revision after primary implantation of the Scandinavian Total Ankle Replacement system: A systematic review. Clin Podiatr Med Surg. 2013;30:237–50.
2. Myerson MS, Aiyer AA, Ellington JK. Revision total ankle replacement. JBJS Essent Surg Tech. 2015;5(2):e7.
3. Roukis TS, Elliott AD. Incidence of revision after primary implantation of the Salto ® mobile version and Salto Talaris ™ total ankle prostheses: a systematic review. J Foot Ankle Surg. 2015;54:311–9.
4. Labek G, Todorov S, Iovanescu L, Stoica CI, Böhler N. Outcome after total ankle arthroplasty-results and findings from worldwide arthroplasty registers. Int Orthop. 2013;37:1677–82.
5. Noelle S, Egidy CC, Cross MB, Gebauer M, Klauser W. Complication rates after total ankle arthroplasty in one hundred consecutive prostheses. Int Orthop. 2013;37:1789–94.
6. Lai WC, Arshi A, Ghorbanifarajzadeh A, Williams JR, Soohoo NF. Incidence and predictors of early complications following primary and revision total ankle arthroplasty. Foot Ankle Surg. 2018 . pii: S1268-7731(18)30325-4; https://doi.org/10.1016/j.fas.2018.10.009.
7. Law TY, Sabeh KG, Rosas S, Hubbard Z, Altajar S, Roche MW. Trends in total ankle arthroplasty and revisions in the Medicare database. Ann Transl Med. 2018;6(7):112.
8. Sadoghi P, Roush G, Kastner N, Leithner A, Sommitsch C, Goswami T. Failure modes for total ankle arthroplasty: a statistical analysis of the

Norwegian Arthroplasty Register. Arch Orthop Trauma Surg. 2014;134:1361–8.
9. Horisberger M, Henninger HB, Valderrabano V, Barg A. Bone augmentation for revision total ankle arthroplasty with large bone defects. Acta Orthop. 2015;86:412–4.
10. Patton D, Kiewiet N, Brage M. Infected total ankle arthroplasty: risk factors and treatment options. Foot Ankle Int. 2015;36:626–34.
11. Demetracopoulos CA, Adams SB Jr, Queen RM, DeOrio JK, Nunley JA 2nd, Easley ME. Effect of age on outcomes in total ankle arthroplasty. Foot Ankle Int. 2015;36:871–80.
12. Steck JK, Schuberth JM, Christensen JC, Luu CA. Revision total ankle arthroplasty. Clin Podiatr Med Surg. 2017;34:541–64.
13. Di Iorio A, Viste A, Fessy MH, Besse JL. The AES total ankle arthroplasty analysis of failures and survivorship at ten years. Int Orthop. 2017;41:2525–33.
14. Elliott AD, Roukis TS. Anterior incision offloading for primary and revision total ankle replacement: a comparative analysis of two techniques. Open Orthop J. 2017;11:678–86.
15. Althoff A, Cancienne JM, Cooper MT, Werner BC. Patient-related risk factors for periprosthetic ankle joint infection: an analysis of 6977 total ankle arthroplasties. J Foot Ankle Surg. 2018;57:269–72.
16. Sansosti LE, Van JC, Meyr AJ. Effect of obesity on total ankle arthroplasty: a systematic review of postoperative complications requiring surgical revision. J Foot Ankle Surg. 2018;57:353–6.
17. Gramlich Y, Neun O, Klug A, Buckup J, Stein T, Neumann A, Fischer S, Abt HP, Hoffmann R. Total ankle replacement leads to high revision rates in posttraumatic end-stage arthrosis. Int Orthop. 2018;42:2375–81.
18. Cody EA, Taylor MA, Nunley JA 2nd, Parekh SG, DeOrio JK. Increased early revision rate with the INFINITY total ankle prosthesis. Foot Ankle Int. 2019;40(1):9–17. https://doi.org/10.1177/1071100718794933.
19. Currier BH, Hecht PJ, Nunley JA 2nd, Mayor MB, Currier JH, Van Citters DW. Analysis of failed ankle arthroplasty components. Foot Ankle Int. 2018. doi: https://doi.org/10.1177/1071100718802589.
20. Cody EA, Bejarano-Pineda L, Lachman JR, Taylor MA, Gausden EB, DeOrio JK, Easley ME, Nunley JA 2nd. Risk factors for failure of total ankle arthroplasty with a minimum five years of follow-up. Foot Ankle Int. 2018. doi: https://doi.org/10.1177/1071100718806474.

14 Revision Total Ankle Arthroplasty: Surgical Technique

Inmaculada Moracia-Ochagavía,
Fernando Noriega-Díaz,
and E. Carlos Rodríguez-Merchán

14.1 Introduction

The number of ankle prostheses performed annually continues to increase due to significant improvements in patient function and satisfaction, significant pain relief, and the preservation of hindfoot mobility. On the other hand, the rate of ankle arthrodesis remains stable. This increase in the number of implanted primary prostheses has led to an increase in revision rates for ankle prostheses. Review rates can vary between 8.4% and 17% in large series with long follow-up periods [1–4] (Fig. 14.1).

Lachman et al. [5] have published failure rates in their series of 10% prosthetic revisions, which are comparable to previously reported failure rates in primary ankle prostheses and tibiotalar arthrodeses [6, 7]. In addition, tibiotalar arthrodesis with allograft block, which was considered the gold standard, frequently engenders complications and reoperations, and the patient is often not satisfied with the intervention. The rate of reoperation after arthrodesis can reach up to 41% often due to the development of osteoarthritis in adjacent joints [8, 9].

I. Moracia-Ochagavía · E. C. Rodríguez-Merchán (✉)
Department of Orthopedic Surgery,
"La Paz" University Hospital, Madrid, Spain

F. Noriega-Díaz
Instituto Internacional de Cirugía Ortopédica del Pie (IICOP), Madrid, Spain

The main challenges in rescuing an ankle prosthesis that has failed include finding the right prosthesis for the revision, exhaustively planning the management of bone defects and underlying infection, and the possible concomitant procedures necessary to achieve good alignment and stability of the ankle prosthetic components.

14.2 Indications and Contraindications

The main indications for revision of an ankle prosthesis include loosening and sinking of the talus component. According to Myerson et al. [10], there are no limits regarding the extent of the collapse or loss of bone stock in the talus, given that nothing prevents the use of a revision system, particularly when a flat cut can be made in the talus. Previously, a significant loss of bone stock in the talus was a contraindication for prosthetic revision. As we will see in this chapter, however, arthrodesis can be avoided using a large structural graft or certain prosthetic models.

Some authors consider the presence of recent or ongoing infection as a contraindication. However, it is possible to perform a rescue and implant a new prosthesis following proper guidelines and planning. The presence of chronic pain or a damaged soft tissue envelope with excessive scarring or previous healing problems can be contraindications.

E. C. Rodríguez-Merchán (ed.), *Revision Total Joint Arthroplasty*,
https://doi.org/10.1007/978-3-030-24773-7_14

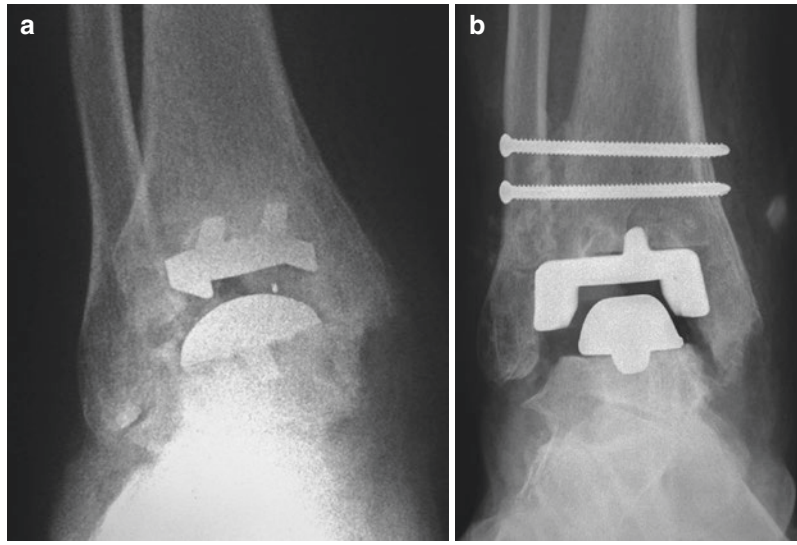

Fig. 14.1 (**a**) Anteroposterior radiograph showing loosening of a Ramses model prosthesis. (**b**) A replacement was performed by Agility prosthesis. It is one of the first revision surgeries performed by the authors. Since no current revision components were available at the time, an Agility prosthesis was implanted with good functional results. To date, no new revision has been necessary. In addition, the arthrodesis of tibiofibular syndesmosis was indicated with this model

14.3 Ankle Prosthesis Revision for Aseptic Loosening With or Without Sinking of the Components

In an ankle prosthesis, the force that supports the bone is at least three times greater than under normal conditions. For this reason, the fixation of the metallic components must ensure appropriate stability during physical activities and must also prevent sinking.

In the aseptic loosening of the tibial component, the cortex of the tibial metaphysis becomes sclera, and in the center the spongy bone mass decreases or bone cysts form. In contrast, when loosening of the talus component occurs, it can increase sclerosis in the anterior and posterior part of the talus, resulting in the formation of cysts in these locations.

We have also frequently observed that those patients who present loosening with prosthetic sinking have vitamin D levels well below normal limits. Future studies will be necessary to observe whether there is a cause-effect relationship; for now, the authors recommend always making a determination of vitamin D levels before revision surgery and supplementing with vitamin D when necessary [11, 12].

When an ankle prosthesis revision surgery is indicated, several problems must be addressed (Fig. 14.2). To determine its importance, we must perform a thorough physical and radiological examination. It is necessary to evaluate the coronal alignment of the leg and hindfoot; for this, we must observe how the patient walks, observing the patient from behind; and also evaluate the alignment while standing, statically, on a podoscope (to detect misalignment in the varus or valgus, or pronation or supination of the midfoot). Regarding sagittal misalignment, equine contracture can be related to a shortening of the *gastrocnemius* muscles or the Achilles tendon, which plays an important role in the correction of the hindfoot.

To evaluate the radiographic evolution, we need to obtain an X-ray of lateral and anteroposterior loading of the ankle and foot before the surgery, and a hindfoot projection (Saltzman view). Occasionally, a lower limb standing radiograph might be necessary to assess varus or valgus deformities of the shaft or tibial metaphysis.

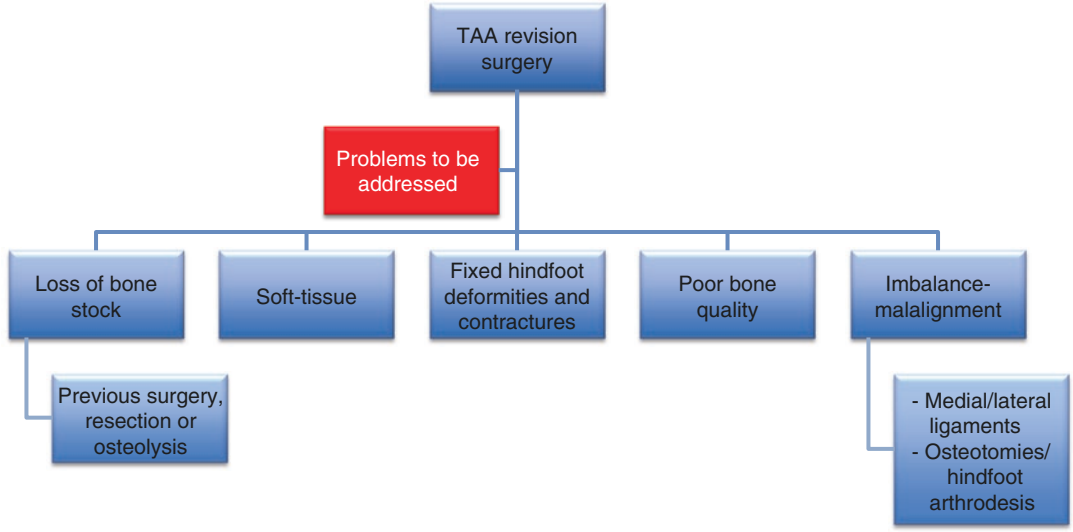

Fig. 14.2 Problems to be addressed when a revision total ankle arthroplasty (RTAA) is indicated. *TAA* total ankle arthroplasty

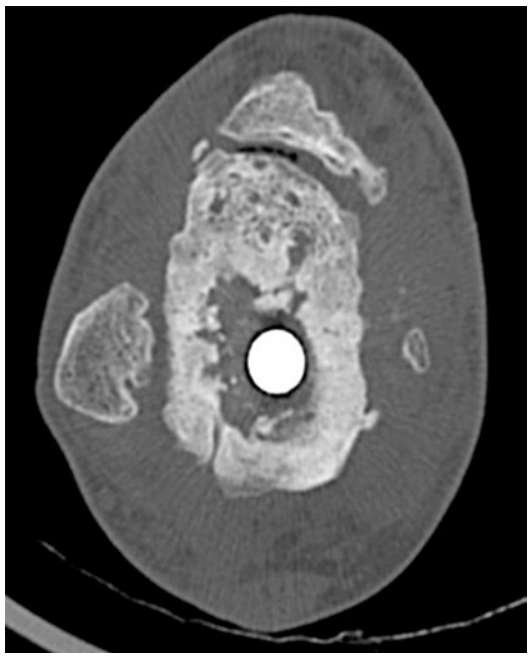

Fig. 14.3 Computed tomography (CT) scan axial cut showing extensive osteolysis and poor bone quality around the tibial stem of the talus component

A computed tomography (CT) scan allows us to determine the extent of bone destruction (Fig. 14.3) and to anticipate the need for bone grafts, custom-made ankle prostheses, or prostheses with diaphyseal anchor tibial stems (such as the INBONE total ankle replacement system), or talar support plates (such as the INVISION total ankle replacement system. Modalities such as single-photon emission CT and fluorodeoxyglucose positron emission CT can identify pathological situations around the prosthetic components.

Hintermann et al. use an algorithm based on the size of the bone defect in the tibia and the talus to plan revision surgeries [13]. However, this approach only appears applicable in the case of using the Hintegra prosthesis and its revision components.

These algorithms are not used in our usual practice. We support other prosthetic models that allow bone defects to be resolved based on stability and diaphyseal support in the case of the tibia or the use of talar plateaus of various sizes that recover a flat surface and with cortical support on which to implant the talar dome.

14.4 Technique for Removing an Ankle Prosthesis

Some essential first steps should be taken to reach the prosthetic implants that have failed.

- With the patient in the supine position, make an incision incorporating the previous anterior incision in the midline.

- Identify and protect the dorsal medial cutaneous branch of the superficial peroneal nerve, which falls superficially to the extensor retinaculum and can be surrounded by scar tissue. The surgeon should keep in mind that fibrous and scar tissue can prevent proper bone preparation, while increasing the risk of neurovascular injury.
- Identify the extensor reticulum and section it longitudinally to the neck of the talus. We use a Vicryl 1 suture to mark and identify both flaps of the retinaculum, and repair it. Next, the interval between the tibialis anterior tendon and the extensor hallucis longus should be deepened, protecting the neurovascular bundle.
- Limit as far as possible the placement of aggressive separators to prevent complications in the healing of soft tissues.
- Once the tibia is exposed, insert the capsule over the ankle joint and place a medial and lateral Hoffman-type separator.
- Extract the loosened prosthetic components. First, extract the polyethylene. Sometimes, according to the prosthetic model, specific instruments can be used for their extraction; however, if the models are older, acquiring these instruments is not always possible. In those cases, the polyethylene must be sectioned in its middle and extracted in parts. Another possibility is to drill the polyethylene on both sides, thus loosening it for its extraction. With respect to the tibial and talar components, they are often loosened and easily removed. If there are areas with good bone anchoring, the use of small chisels can be helpful to detach the implant, preserving as much bone as possible.
- The medial and lateral droplets should be debrided exhaustively, and the posterior capsule should be resected, avoiding the neurovascular structures in the posteromedial area.

When we have the bony surfaces free of prosthetic implants, we can focus on each specific area: tibia and talus.

14.5 Aseptic Loosening of the Tibial Component

One of the major surgical concerns is the bone stock that can remain after the extraction of the prosthesis. Some causes for this loss of bone stock include an excessive resection in the primary intervention, loosening and sinking of the component, osteolysis, cyst formation, and bone loss during extraction and infection. It is essential to observe bone surfaces with good bleeding after removing the prosthesis and to perform a thorough debridement of the fibrosis.

Before beginning the surgical technique for the prosthesis to be implanted, we attempt to get flat and parallel surfaces to the ground, making cuts with a saw guided by fluoroscopy (Fig. 14.4). If the prosthesis to be implanted is not a revision, it is very important to keep the anterior and posterior cortex as undamaged as possible, given the tibial plate will rest on that tibial cortical ring.

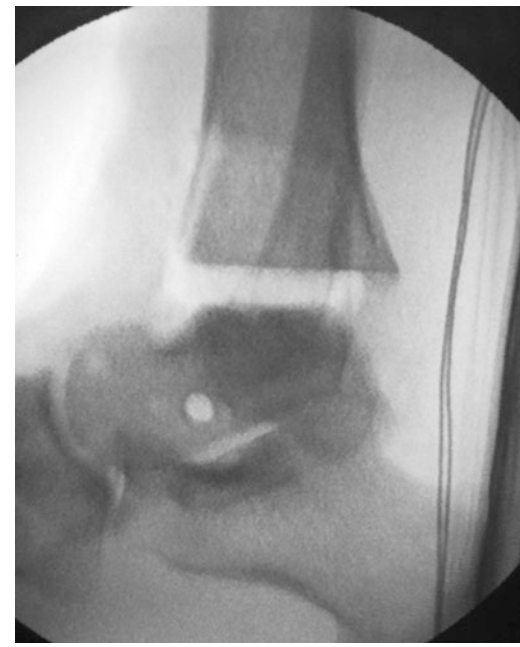

Fig. 14.4 Intraoperative fluoroscopy image after making tibial and talar cuts parallel to each other and parallel to the ground plane before placing the cutting templates of a particular prosthetic model

However, if the quality of the distal metaphyseal cortices is poor, it is useful to opt for a prosthesis with a tibial stem, which can have a variety of lengths (INBONE II prosthesis) and achieve greater diaphyseal support, without completely depending on the distal tibial cortex.

We consider from the outset that the implant support on the distal tibial cortices of our patients will be insufficient, and a greater diaphyseal support will always be necessary to achieve a satisfactory stability and to decrease the risk of subsidence of the tibial component (Fig. 14.5).

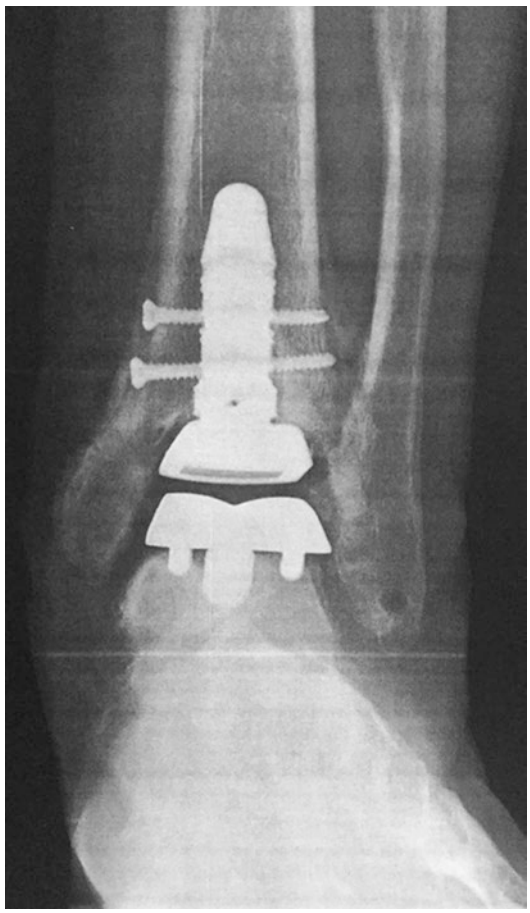

Fig. 14.5 Anteroposterior radiograph showing INBONE II prosthesis with modular tibial stem, implanted after prosthetic revision due to loosening of the tibial and talar components. It was not necessary to use revision components. Note also the osteosynthesis that was performed in an intraoperative tibial malleolus fracture

If there are important cysts or bone defects, they should first be debrided and curetted until the healthy subchondral bone is visible. Afterward, the cysts should be filled with a cancellous bone autograft of the proximal tibia and/or of the ipsilateral iliac crest. The additional use of cement can secure the prosthetic anchor and provide good results. Opt for an allograft only in cases needing large amounts of bone graft, which is unlikely, given that a sufficient autograft is typically obtained (which also has better characteristics for osteointegration). It is important to compact it well to prevent early resorption.

In case of a longitudinal bone defect, to restore the height of the joint line, thicker revision tibial components can be used, such as the Hintegra prosthetic system with 8 mm and 12 mm tibial components, or the INVISION prosthetic system that adds +4 mm or + 8 mm at the usual height of the INBONE II tibial component (Fig. 14.6).

There is also the possibility of using a structural autograft of the iliac, bicortical, or tricortical crest, in case of defects in the cortical ring of the distal tibia. Osteosynthesis is performed of the autograft to the rest of the intact tibia, while predicting the position of the definitive implants.

If there is a collapse of the tibial component, its depth must be estimated and any potential misalignment corrected. As we have previously noted, parallel tibial bone cuts to the healthy area can be performed, using spongy or structural autografts or using specific cutting templates of the prosthesis to be implanted.

If the tibial resection to be performed is very proximal and leaves a small bridge between the medial corner of the tibia and the tibial malleolus, it can lead to intraoperative fracture and instability of the revision prosthesis. In these cases, a prefixation of the malleolus with K-wires or screws is performed. As we will see in the next chapter, tibial malleolus fractures are low-grade complications and do not influence the prognosis of the prosthesis. If the tibial resection reaches the level of the syndesmosis, it is necessary to perform an arthrodesis of the tibiofibular syndesmosis with two cortical screws of 3.5 mm compression.

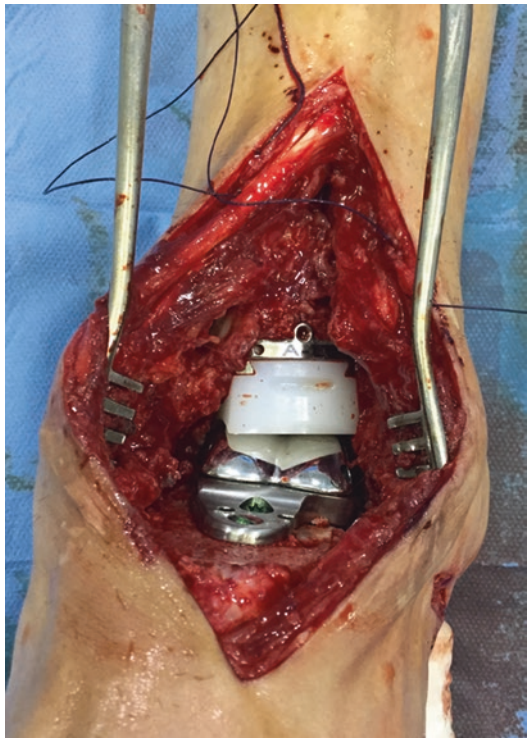

Fig. 14.6 Intraoperative image in which a large polyethylene insert is observed to restore the height of the joint line. The talar component rests on the platform of the INVISION revision system

14.6 Aseptic Loosening of the Talar Component

When there is a loosening of the talar component it is important to evaluate the degree of subsidence of the component and the size of the bony cysts. For this purpose, the classification described by Ellington et al. can be useful [14].

Based on our experience, there are currently several options for loosening, with or without sinking of the felling component:

- In grade 1, fill bone cysts with impacted cancellous autograft and use a talar component with a flat bottom surface, such as the Hintegra prosthetic system, the Salto-Talaris XT revision prosthesis, or the INBONE II system with a central stem and two anterior pegs is recommended (Fig. 14.7).
- In grade 2 and especially in grade 3, we recommend a novel prosthetic system known as INVISION (Wright Medical Technologies, Inc., Arlington, TN, USA). In this system, there is the possibility of an asymmetrical talar dish of five different sizes as well as the possibility of adding +3 mm of thickness. This system is

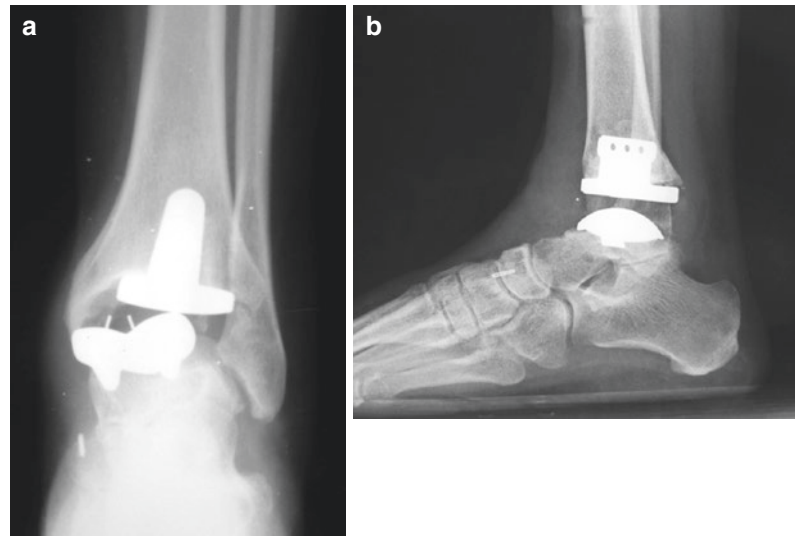

Fig. 14.7 (**a**) Loosening of the talar and tibial components, without sinking or loss of bone stock. (**b**) Prosthetic revision was performed with a Salto-Talaris prosthesis. It was not necessary to use the revision components, given there was no lack of bone stock

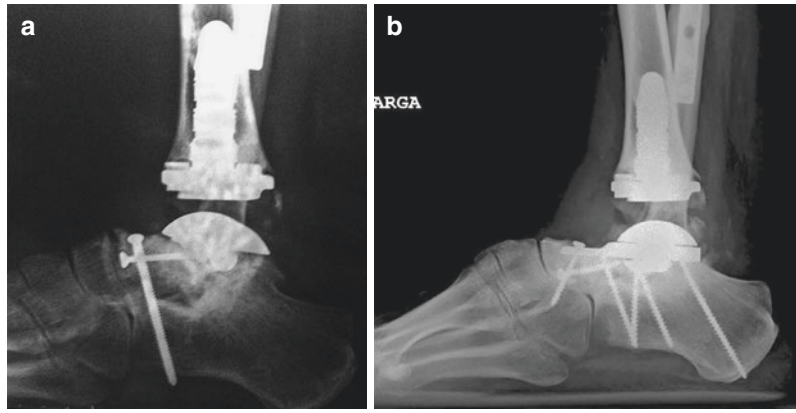

Fig. 14.8 (**a**) The image shows loosening and sinking of the INBONE II component together with subtalar arthrodesis. (**b**) A prosthetic revision was performed with the INVISION revision system. This system consists of a talar platform with screws up to the calcaneus to give greater stability, and a metal supplement to fill the bone defect of the talus after having extracted the loosened component. A higher polyethylene was also added

designed to maximize the cortical coverage of the talus. In addition to gaining stability, it has perimeter holes for 2.7-mm and 3.5-mm screws blocked and not blocked (Fig. 14.8).

One of the most important steps in revision surgery is to fill bone defects or cysts with autograft to provide a dense bone stock for the implantation of the prosthetic component. There are also prosthetic systems (INVISION) that have two types of increases available (central and oblong), with five different diameters. If bone defects persist in the talus, an increase of this type to the talus plate can be added to fill them.

In patients with obesity, patients with symptomatic arthritis in the subtalar joint, and patients with subtalar grade 3 subsidence, it is advisable to perform subtalar arthrodesis.

Sometimes it is necessary to place a distractor (Fig. 14.9) in the medial area of the ankle to help obtain a neutral alignment and balance the ligamentous tension. The release of collateral ligaments, however, is rare.

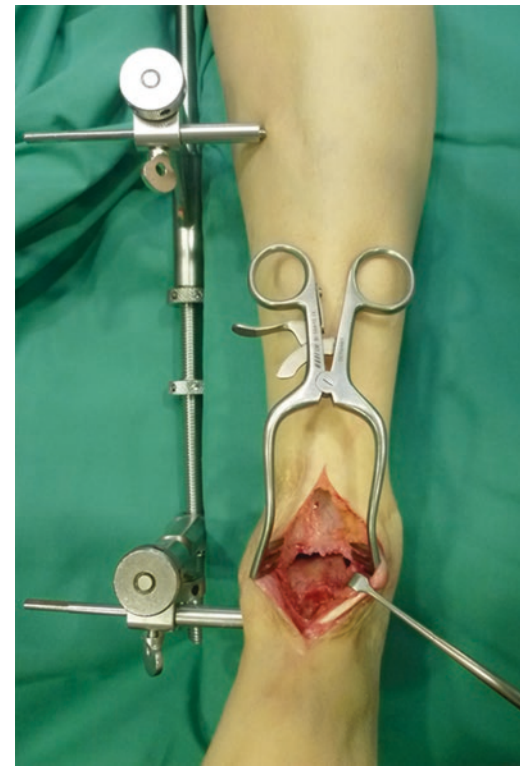

Fig. 14.9 Placement of a femoral distractor in the medial area of the ankle to access the joint space. It can be used in primary ankle prosthetic surgery or revision surgery

14.7 Septic Loosening of Total Ankle Prosthesis

Deep periprosthetic infections can be classified into acute (less than 4 weeks after the intervention) or chronic/late (after 4–6 weeks). When we suspect a deep infection, the first step is to perform an arthrocentesis using a sterile technique. The fluid will be sent for gram stain and

cultures of aerobes, anaerobes, acid-resistant stain, and fungi.

Afterward, antibiotic treatment can be started if the symptoms worsen in the interval between the clinical evaluation and the definitive treatment. This empirical treatment should cover the skin flora and Gram-negative organisms. If there is a history of colonization by methicillin-resistant *Staphylococcus aureus* (MRSA), it should be treated with antibiotics that cover MRSA.

Laboratory markers include the erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), and a complete blood count. Procalcitonin has only been shown to be useful for finding hidden sepsis in intensive care patients.

The radiographic evaluation should include the following:

- X-rays: In these, periprosthetic radiolucencies, loosening, or collapse of the components can be observed, although by themselves they are not diagnostic of infection. If liquid levels or gases in the soft tissues accompanied by systemic signs of infection are observed, a deep infection is suggested, which is a surgical emergency.
- Magnetic resonance imaging (MRI) can be useful in late infections (abscesses), but only after administering gadolinium.
- (99 m) Tc-ciprofloxacin: Does not allow differentiation of infection from aseptic loosening [15].
- Indium-111/Tc99m dual window scan: Maximizes the accuracy and specificity of the image [16].

In case of acute infection with susceptible organisms and well-anchored components, only a polyethylene replacement can be performed. On the other hand, if there is intraarticular pus in the acute phase or if the infection is detected after 6 weeks, the implants must be removed and the bone surfaces and devitalized soft tissues debrided. Then, a cement spacer with antibiotics should be placed. Bibbo et al., in 2005, used a negative pressure therapy in the wound with direct instillation of antiseptics such as sodium hypochlorite (Dakin's solution); thus, they subsequently found a decrease in the number of debridements to be performed [17]. The implants must be sent for a direct culture. If the cultures of the tissues and fluids are negative, a bacterial 16 s CRP and sonication of the removed components should be requested. Sonication removes biofilms and uncovers hidden pathogens [18].

Intravenous antibiotic treatment will be determined by the results of the sample cultures taken intraoperatively. The treatment should last at least 6–8 weeks, and a determination of ESR and CRP should be made every 2 weeks.

We can consider the placement of a new prosthesis if:

- The patient has undergone at least 6–8 weeks of specific antibiotic treatment according to the cultures.
- Laboratory markers have normalized.
- Any residual infection has been ruled out by both an Indium-111/Tc-99 m dual window scan as with the cultures and a 16 s CRP of the bone and soft tissue biopsy.
- There is an adequate residual bone stock of good quality.

We consider that the INBONE II and INVISION prosthetic systems are a satisfactory choice in cases of bone loss. There is controversy in relation to whether the implants should be cemented. On one hand, from a microbiological point of view, some benefits of cement can be derived from antibiotics. However, more than one antibiotic would be needed in the cement, which would decrease its mechanical characteristics. Also, if there is a new prosthetic failure, the extraction would be more complicated (increasing the loss of bone that remains adhered to said cement). Thus, we are in favor of not cementing the implants.

Certain circumstances prohibit in some way the placement of a new prosthesis after a deep prosthetic infection: for example, a patient with poor general condition, organisms with high multiresistant virulence, massive bone loss, or an unstable soft tissue envelope.

14.8 Additional Surgeries in Ankle Prosthesis Revision Surgery

As already mentioned, during the physical examination it is important to note problems of malalignment and instability of the ankle and foot. At other times, during the surgical procedure, once the prosthesis is implanted, these problems manifest themselves more clearly. In any case, the malalignment and instability must be resolved at the same surgical time as the prosthetic revision. Any residual deformity in the hindfoot has a negative impact on the mechanics of the ankle and will lead to early failure of the implanted prosthesis.

A misalignment in the varus or valgus of less than 10° can be easily compensated by adjusting the tibial cuts. Major deformities should be corrected by supramalleolar osteotomies (wedge closure or opening). In these cases, we prefer an oblique opening osteotomy with the use of iliac crest autograft. Generally, it is attempted in a single procedure; in revision surgeries, however, each case must be individualized by assessing the difficulty or the surgical time of the revision itself as well as considering the individual characteristics of the patient.

There are cases with medial insufficiency of the tibial malleolus, hypoplasia, or progressive atrophy in a very pronounced varus. For these patients, performing a longitudinal osteotomy of the tibial malleolus would be indicated to lower it, recreating an adequate medial slide and improving stability (Fig. 14.5).

If the problem lies in the hindfoot, a lateralization osteotomy or medialization must be performed, depending on whether it is a varus or valgus. The midfoot or the forefoot should not be forgotten, given they also play an important role in the success of revision prostheses. Any deformity must be resolved, either with arthrodesis of certain joints or with osteotomies in those rare cases in which the joint does not present degenerative changes. If it is an ankle in valgus with medial instability due to insufficiency of the deltoid ligament, it must be reconstructed with a semitendinosus autograft plasty, performing a tunnel in the tibial malleolus to anchor it to two points in the talus.

In cases of prosthetic revision, the subtalar joint is usually painful and there are degenerative changes, for which a subtalar arthrodesis will need to be added that will also correct alignment defects in the hindfoot. We recommend in these cases to respect the vascularization of the interosseous ligament when performing joint debridement. Damage to the interosseous ligament can result in ischemia of the talus and promote sinking of the talus component (Fig. 14.8b).

After the implantation of the revision prosthesis or the performance of an osteotomy, instability of the lateral ligament complex can sometimes occur. In that case, it must be reconstructed in the same intervention. To this end, an anatomical reconstruction of the anterior talofibular and talocalcaneal ligament must be performed with a semitendinosus plasty obtained from the patient. Thus, we ensure the lateral stability of the ankle and provide healthy tissue for the reconstruction of the ligaments.

14.9 Postoperative Treatment

Immediate postoperative treatment is also part of the surgical process, which begins from the moment we initiate the closure of the wound [19]. Usually during primary prosthetic surgery or ankle revision there is no significant blood loss; however, we have adopted a protocol for the prevention of blood loss in knee prostheses that has been shown to reduce bleeding and hospital stay after the intervention [20].

This protocol consists of the following:

- Two intravenous doses of tranexamic acid (15 mg/kg in 100 mL of 0.9% saline): the first before releasing the tourniquet and the second 3 h after the surgery.
- Pneumatic turnstile with a pressure of 100 mmHg above the systolic pressure.
- A 10-mm drain without vacuum (it will open 2 h after the intervention).
- Intra-articular infiltration with the following solution: 80 cc of saline with 0.3 mg of

adrenaline, 10 mg of morphine chloride, 100 mg of tobramycin, 6 mg of betamethasone sodium phosphate, 6 mg of betamethasone acetate, 200 mg of ropivacaine (30 cc in posterior capsule before prosthetic implantation, and 50 cc in synovium, anterior capsule, and subcutaneous tissues after implantation).

Close the extensor retinaculum with loose Vicryl 2/0 stitches and the skin with an Allgöwer–Donati suture with 3/0 nylon, always maintaining the ankle in neutral dorsiflexion. Each wound should be covered with a Linitul-impregnated dressing and a compression bandage applied, following the guidelines of Hsu et al. [21]. A double posterior and U-shaped splint should be placed on the compression bandage. At 48 h, the first postsurgical treatment should be performed, removing the drainage and again applying the same type of compression bandage and placing a double splint.

For the first 15 days, the patient must rest in a bed and armchair, with the operated lower limb raised to the level of the heart, drink at least 2–3 L of fluid per day, and perform lower limb mobilization exercises as indicated by the rehabilitation team (physiotherapy).

After 2–3 weeks, a new treatment of the wound is performed and the stitches are removed. A Cam-Walker orthopedic boot can be placed, but without loading on the operated foot. The patient is able to move small distances with the use of crutches. The boot can be removed 2–3 times a day to perform ankle mobilization exercises. Partial loading can occur from 6–8 weeks if the radiological tests show that everything is correct.

14.10 Conclusions

The surgical technique of prosthetic revision first requires very careful planning, from the selection of the right candidate to the complementary surgeries that must be performed so that the results are satisfactory and durable. The most important aspect that concerns specialists is the deficit and bone quality observed in imaging tests on which we rely after the removal of the implants. In the prosthetic revision of the ankle, the use of a spongy autograft is practically a norm (to fill defects and cysts making an exhaustive impaction), using a structural autograft for larger defects. We also consider cement a good option. The new prosthetic designs have prompted revisions that a few years ago were destined for an arthrodesis. Tibial revision components with modular stems or talar platforms of various sizes and shapes, or even with supplements, safely support the talar dome. In those patients with septic loosening, it is also possible to perform a prosthetic revision in two stages, following the premises used in cases of prosthetic knee or hip infection. A fundamental part of most prostheses' long-term success are the additional surgeries. Lengthening the Achilles tendon, calcaneal osteotomies, proximal tibia, and ligamentoplasties are mandatory maneuvers for the correct functioning, stability, and alignment of the prosthesis. Multimodal postoperative treatment is also essential. Care of the soft tissues and a decrease in swelling and postoperative bleeding help make the postoperative evolution more satisfactory for the patient and also shorten the hospital stay.

References

1. Fevang BT, Lie SA, Havelin LI, Brun JG, Skredderstuen A, Furnes O. 257 Ankle arthroplasties performed in Norway between 1994 y 2005. Acta Orthop. 2007;78:575–83.
2. Henricson A, Nilsson JA, Carlsson A. 10-Year survival of total ankle arthroplasties: a report on 780 cases form the Swedish Ankle Register. Acta Orthop. 2011;82:655–9.
3. Henricson A, Skoog A, Carlsson A. The Swedish Ankle Arthroplasty Register: an analysis of 531 arthroplasties between 1993 and 2005. Acta Orthop. 2007;78:569–74.
4. Prissel MA, Troukis TS. Incidence of revision after primary implantation of the Scandinavian Total ankle Replacement System: a systematic review. Clin Podiatr Med Surg. 2013;30:237–50.
5. Lachman JR, Ramos JA, Adams SB, NunleyII JA, Easley ME, DeOrio JK. Patient-reported outcomes before and after primary and revision total ankle arthroplasty. Foot Ankle Int. 2019;40:34–41.
6. Dekker TJ, Walton D, Vinson EN, Hamid KS, Federer AE, Easley ME, et al. Hindfoot arthritis progression

and arthrodesis risk after total ankle replacement. Foot Ankle Int. 2017;38:1183–7.
7. Lawton CD, Bennet AB, Dekker RG, Prescott A, Kadakia AR. Total ankle arthroplasty versus ankle arthrodesis: a comparison of outcomes of the last decade. J Ortho Surg Res. 2017;12:76.
8. Berkowitz J, Clare MP, Walling AK, Sanders R. Salvage of failed total ankle arthroplasty with fusión using structural allograft and internal fixation. Foot Ankle Int. 2011;32:S493–502.
9. Kitaoka HB, Romness DW. Arthrodesis for failed ankle arthroplasty. J Arthroplast. 1992;7:255–61.
10. Myerson MS, Aiyer AA, Ellington JK. Revision total ankle replacement. Based on an original article. J Bone Joint Surg Am. 2013;95:2112–8.
11. Zajonz D, Prager F, Edel M, Möbius R, Daikos A, Fakler JK, et al. The significance of the vitamin D metabolism in the development of periprosthetic infections after THA and TKA: a prospective matched-pair analysis of 240 patients. Clin Interv Aging. 2018;13:1429–35.
12. Maier GS, Horas K, Seeger JB, Roth KE, Kurth AA, Maus U. Is there an association between periprosthetic joint infection and low vitamin D levels? Int Orthop. 2014;38:1499–504.
13. Hintermann B, Zwicky L, Knupp M, Henninger HB, Barg A. Hintegra revision arthroplasty for failed total ankle prosthesis. J Bone Joint Surg Am. 2013;95:1166–74.
14. Ellington JK, Gupta S, Myerson MS. Management of failures of total ankle replacement with the agility total ankle arthroplasty. J Bone Joint Surg Am. 2013;95:2112–8.
15. Love C, Marwin SE, Palestro CJ. Nuclear medicine and the infected joint replacement. Semin Nucl Med. 2009;39:66–78.
16. Teller RE, Christie MJ, Martin W, Nance EP, Haas DW. Sequential indium-labeled leukocyte and bone scans to diagnose prosthetic joint infection. Clin Orthop Relat Res. 2000;373:241–7.
17. Bibbo C, Patel DV, Gehrmann RM, Lin SS. Chlorhexidine provides superior skin decontamiantion in foot and ankle surgery: a prospective randomized study. Clin Orthop Relat Res. 2005;438:204–8.
18. Scorzolini L, Lichtner M, Iannetta M, Mengoni F, Russo G, Panni AS, et al. Sonication technique improves microbiological diagnosis in patients treated with antibiotics before surgery for prosthetic joint infections. New Microbiol. 2014;37:321–8.
19. Roukis TS, Berlet GC, Bibbo C, Hyer CF, Penner MJ, Wünschel M. Primary and revision total ankle replacement: evidence-based surgical management. Cham: Springer; 2016.
20. Ortega-Andreu M, Talavera G, Padilla-Eguiluz NG, Perez-Chrzanowska H, Figueredo-Galve R, Rodríguez-Merchán EC, et al. Tranexamic acid in a multimodal blood loss prevention protocol to decrease blood loss in revision total knee arthroplasty: a cohort study. Open Orthop J. 2016;10:439–47.
21. Hsu AR, Franceschina D, Haddad SL. A novel method of postoperative wound care following total ankle arthroplasty. Foot Ankle Int. 2014;35:719–24.

Revision Total Ankle Arthroplasty: Complications and Results

15

Inmaculada Moracia-Ochagavía
and E. Carlos Rodríguez-Merchán

15.1 Introduction

Current literature on the procedure of revision total ankle arthroplasty (RTAA) is scarce, and it is even scarcer in relation to the complications derived from this intervention. As described in the previous chapter, the revision of an ankle prosthesis is a demanding procedure that requires thorough presurgical planning that foresees all the possible complications and thus avoids them or is prepared to resolve them. Both foreseeable and other complications can arise unexpectedly, either intraoperatively or in the immediate postoperative period. In this chapter we review the main complications and results of RTAA.

15.2 Complications of Revision Total Ankle Arthroplasty

During the 1990s, the De Puy Agility prosthesis (Warsaw, IN, USA) was the most commonly implanted total ankle arthroplasty in the United States, the only one approved by the Food and Drug Administration (FDA). Williams et al. have reported a complication rate of 31.4% in their retrospective review of perioperative complications during the review of the Agility prostheses and their replacement by the INBONE II system (Wright Medical Technology, Memphis, TN, USA) [1]. These authors affirmed that the postoperative complications observed in their series were not specific to revision surgery of the ankle prostheses (Table 15.1).

Occasionally, isolated cases of vascular lesions have been reported, such as iatrogenic arteriovenous fistulas or pseudoaneurysms of the posterior tibial artery [2]. Although they are not frequent complications in prosthetic ankle

Table 15.1 Complications of revision total ankle arthroplasty (RTAA)

Intraoperative complications	Acute perioperative complications	Late postoperative complications
Malleolar fracture (medial or lateral)	Prosthetic dislocation	Loosening and subsidence of talar or tibial component
Distal tibial shaft fracture	Wound dehiscence	Pain
	Tibialis posterior nerve compression	Joint stiffness (arthrofibrosis)
	Neuroma of deep peroneal nerve	Chronic infection
	Malleolar nonunion	
	Acute infection	

I. Moracia-Ochagavía
Department of Orthopedic Surgery,
"La Paz" University Hospital-IdiPaz, Madrid, Spain

E. C. Rodríguez-Merchán (✉)
Department of Orthopedic Surgery,
"La Paz" University Hospital, Madrid, Spain

E. C. Rodríguez-Merchán (ed.), *Revision Total Joint Arthroplasty*,
https://doi.org/10.1007/978-3-030-24773-7_15

replacement, their probability is increased in revisions due to the exhaustive debridement and the alteration in the habitual anatomy.

Glazebrook et al. have proposed a classification that categorically divides complications of prosthetic ankle surgery into low, medium, and high grade [3]. Low-grade complications are very unlikely to lead to implant failure (0%), medium-grade complications lead to revision in 17%–45% of cases, and high-grade complications cause implant failure in 69%–81%. However, Gadd et al. later proposed a simplification of this classification. When they applied the Glazebrook classification to their series of ankle prostheses they observed that, except for intraoperative fractures and wound dehiscence, the remaining complications had an incidence of prosthetic failure greater than 50% [4]. Therefore, Gadd et al. proposed only two grades: low grade (intraoperative fractures and wound dehiscence) and high grade (the remaining complications).

Roukis and Simonson observed a complication rate of 25% (8 patients) in a series of 32 patients with the Agility or Agility LP ankle prosthesis in which a revision was performed [5]. Most (87.5%) were classified as low grade. The remaining complications (12.5%) were unclassifiable and were related to unsolved neuropathic symptoms. There were no complications considered high grade in this series. It is also worth noting in this series that 75% of the complications occurred in the initial phase of the learning curve whereas only 25% (minor healing problems) arose in the final phases of the learning curve. Roukis and Simmonson concluded that, when comparing these results with the complications of the Agility or Agility LP primary prosthesis, the revision of this specific ankle prosthesis system during the surgeon's learning period can be carried out safely when performed by a foot and ankle specialist [5].

15.2.1 Low-Grade Complications

15.2.1.1 Intraoperative Bone Fractures

In general, this is a relatively common complication in prosthetic ankle surgery. In revision surgery, the likelihood of fracture of the malleoli is notable due to the decrease in bone stock, osteoporosis due to disuse, or simply due to removing prosthetic implants or placing the new prosthesis.

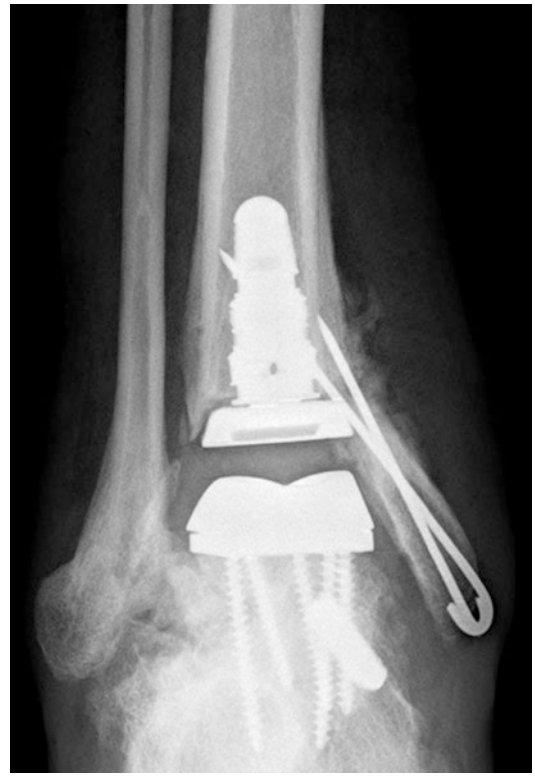

Fig. 15.1 Intraoperative fracture of the tibial malleolus during revision total ankle arthroplasty (RTAA) with INBONE II prosthesis. Reduction and bone fixation were performed with two percutaneous K wires. Two months after the intervention, bone healing of the fracture can be observed with the presence of bone callus

Malleolar fractures (Fig. 15.1) are more frequent than fractures of the tibial diaphysis. The postoperative evolution of cases in which there has been a fracture of the tibial malleolus or peroneus, as well as in the distal tibia, is similar to those patients who have not had intraoperative fractures [1].

In a retrospective review, Cody et al. observed up to 16 periprosthetic fractures, of which 3.5% required revision of the prosthesis or removal of the components [6]. In addition, patients with a bone mineral density low in the tibia, measured in Hounsfield units (HUs) in the preoperative CT, was strongly associated with a risk of periprosthetic

fractures. Therefore, they recommend that an internal prophylactic fixation of the tibial malleolus be performed in patients with less than 200 HU.

15.2.1.2 Problems with Surgical Wound Healing

An important risk factor is a poor previous condition of the soft parts in the anterior ankle area. We must assess previous scars and a history of wound dehiscence.

It is important to place an adequate compressive bandage after the intervention to avoid edema and excessive scarring, as recommended in detail by Hsu et al. in their article [7]. Roukis and Simonson recommend making a window over the anterior incision in the padding under the plaster, and then placing a Robert Jones compression bandage and a molded posterior splint [5]. In this way, contact pressure on the anterior incision is limited and the Robert Jones bandage helps to reduce edema during the postoperative period.

Even with this approach and with intra- and postoperative precautions to avoid soft tissue contusion, wound dehiscence might occur in the first 2–3 weeks.

In most cases, the problem is superficial and is resolved with local wound cleaning and oral antibiotics. Those cases with a torpid evolution and deeper involvement might require plastic surgery to create cover flaps.

15.2.2 High-Grade Complications

15.2.2.1 Acute or Chronic Deep Infection

Myerson et al. did not find any deep prosthetic infection after the revision of the ankle prosthesis in their series [8]. This result is unlike the 3.2% rate of deep infections observed after implanting the Agility and Agility LP primary prosthesis or the 0.7% rate of profound infections diagnosed after implanting the Salto Talaris primary prosthesis.

In any case, Roukis and Simonson present great concern in this regard, and they recommend increasing efforts to minimize infection using the following protocol [5]:

- Minimize the traffic and the number of people in the operating room to the minimum.
- One week prior to surgery, the patient should perform a 5-min wash of the lower limb daily with 4% chlorhexidine gluconate.
- Validated surgical preparation:
  - Perform 3-min foot, ankle, and leg wash with sponges impregnated with chlorhexidine gluconate 4%.
  - Paint with topical alcohol solution and 1% iodine (1 gr iodine/100 ml ethyl alcohol).
  - Cover the fingers with a waterproof barrier.
  - Intermittently repaint exposed skin with 10% povidone iodine solution.
  - Irrigate the surgical site with a pulsatile washing system impregnated with 50,000 IU of bacitracin solution.
  - Ensure a laminar flow system in the operating room without ultraviolet lights.
  - Ensure each member of the surgical team uses double surgical masks.

15.2.2.2 Prosthetic Dislocation

This complication is infrequent and requires surgical intervention for replacement or repositioning of poorly positioned prosthetic components. Alternatively, we can assess medial or lateral instability, which would require ligamentous rebalancing:

- Reconstruction of the lateral ligament complex, performed in our case preferably with ipsilateral semitendinosus plasty.
- In the case of an insufficiency of the deltoid ligament, we opt for a hemitendon reconstruction of the posterior tibial tendon through a hole in the tibial malleolus or a descent osteotomy of the tibial malleolus (Fig. 15.2).

In some cases it is also necessary to realign the ankle, perform osteotomies on both malleoli, and place a thicker component [1].

15.2.2.3 Loosening and Sinking of the Talar Component

The main concern in the prosthetic revision of the ankle is ensuring a good anchoring of the

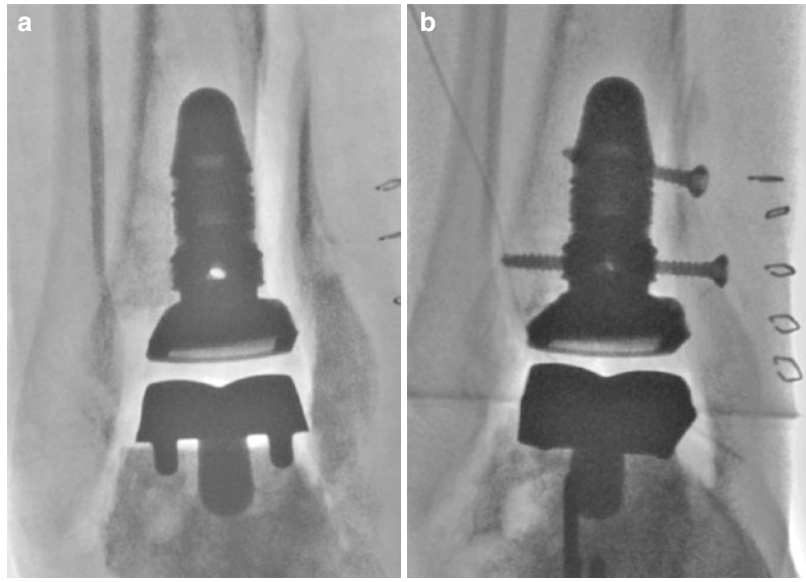

Fig. 15.2 Revision total ankle arthroplasty (RTAA) with medial instability. (**a**) A tibial malleolar descent osteotomy was performed to give stability to the prosthesis. (**b**) Note the descent of the tibial malleolus and the bone fixation performed with two 3.5-mm compression screws

components on deficient bone stock. The flat components are able to accommodate the transmission of forces at the bone-implant interface although the contact area is often sparse. Filling the defects with cancellous bone and bone matrix can help improve bone growth on the prosthetic components (Fig. 15.3).

Hinterman et al. performed a retrospective review of patients undergoing prosthetic revision using the prosthetic components of the HINTEGRA model [9]. They observed that 15% of the 117 revision arthroplasties failed and needed surgical treatment. In four (3.4%) patients there was a loosening of the tibial complement; in five (4.2%) patients there was a loosening of the talar component, and a loosening of both components occurred in two (2.3%) patients. The loosening rate of the components was higher in those with isolated hydroxyapatite coverage than in those with double coverage, a statistically significant result.

Myerson et al. evaluated 41 patients after a prosthetic revision with a mean follow-up of 49.1 months. In their publication, the authors provide a system to classify the severity of prosthetic sinking from 1 to 3 and predict the results after the revision [8]:

- Grade 1: there is a minimum subsidence.
- Grade 2: the talar component has sunk into the talus but not to the subtalar joint.
- Grade 3: the talar component has migrated to the subtalar joint.

In this way, they observed that preoperative subtalar sinking was a significant predictor of the results after a revision.

15.3 Results

We recommend the INBONE II prosthetic design, given it offers a modular tibial component and provides a support for the prosthesis in the medullary canal, adding greater stability. This support is crucial in cases of revision with substantial loss of bone on which stable fixation of the tibial component cannot be relied. In addition, this system allows us to add additional tibial components depending on the amount of support needed and the bone quality of the distal tibia.

Another system to consider is the Invision Total Ankle Revision System. For a prosthetic revision of the ankle due to subsidence of the talus component with significant bone stock deficit, the talar component of this revision system offers a flat implant in the form of a plate and fixation with screws on which to place the talar dome. There are plates of different sizes, thicknesses, and lengths, which support the talar dome on a flat surface and with good cortical support at

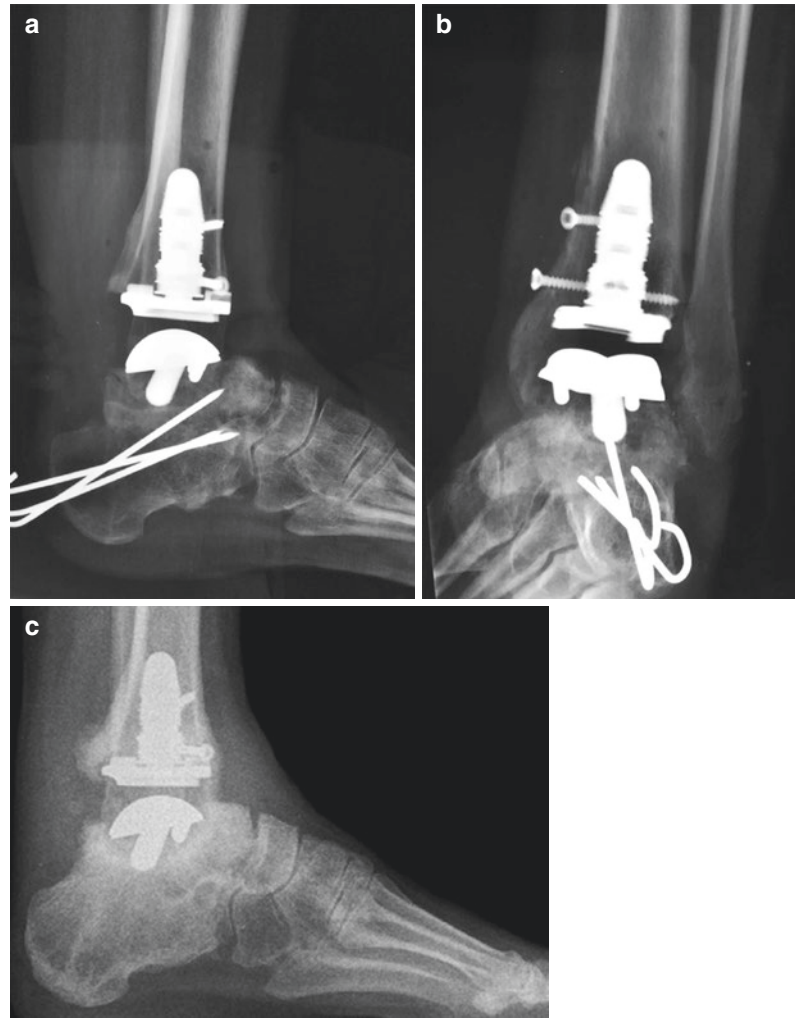

Fig. 15.3 Patient with a history of talar necrosis after fracture. Revision total ankle arthroplasty (RTAA) with INBONE II prosthetic system was performed. As an additional surgery, tibial malleolar descent osteotomy and calcaneal valgus osteotomy were performed. Note subtalar arthrodesis performed previously. The talar component is observed with inclination in dorsal flexion (**a**). Anteroposterior radiographic view taken 3 months after RTAA (**b**). Lateral radiograph taken 9 months after RTAA. Note the loosening and sinking of the talar component with periprosthetic osteolysis (**c**)

the periphery and an even distribution of forces throughout the loading surface (Fig. 15.4).

15.3.1 Range of Motion

In a series of patients published by Myerson et al., data were presented regarding mobility after revision of the ankle prosthesis [8]. The range of motion increased 5°, from 18° preoperatively to 23° postoperatively. The improvement was in plantar flexion.

Hintermann et al. observed in their series a small increase in the range of motion from the clinical point of view, from 28.5° in the preoperative to 32.9° in the postoperative period [9]. Under fluoroscopy, the average range of motion of the ankle was 29.6°.

In a study by Hordyk et al., a significant increase in the range of ankle movement of 15% and a reciprocal reduction in the range of midfoot mobility of approximately 30% were identified [10]. This result demonstrates that by improving the mobility of the ankle after revision of an ankle prosthesis, there is a reduction in the compensatory mobility of the midfoot that was required for walking.

Thus, increasing the range of mobility is not one of the main advantages of prosthetic ankle revision surgery. However, those few degrees gained, together with the stability of the implants and the decrease in pain, provide

patients with significant clinical improvement and less risk of affectation of neighboring joints (Fig. 15.5).

15.3.2 Clinical Results

Myerson et al. presented a series of 41 patients for whom a prosthetic revision was performed [8]. Of these patients, after 50 months of follow-up, 34 (82%) maintained the new implants, in 5 patients a rescue arthrodesis was necessary, and in 2 an amputation had to be performed. The patients presented improvements in their scores on the American Orthopedic Foot and Ankle Society (AOFAS) scale of 65 points, on the Short Form-12 scale of 93.5 points, and a VAS score of 4.

Some 74% could rejoin their previous job, but only 44% could recover their previous level of activity. We conclude that the most important predictor of poor results, based on the AOFAS scale, is the degree of subsidence of the talus component in the preoperative period. Patients should be informed that although good or excellent results can be obtained after an ankle prosthesis revision, less than half of the patients manage to reach their previous level of activity.

In the series by Hintermann et al., of 117 revised ankle prostheses, 93% (109) was successful with a significant improvement in the AOFAS hindfoot scale due to a slight increase in ankle mobility as well as substantial improvements in both pain and function [9]. The clinical results and failure rates of this ankle revision series were comparable to those observed after primary ankle prostheses. The estimated survival of the components was 83% at 9 years and was better in the components with double hydroxyapatite coverage.

It is also noteworthy that the correlation between bone stock deficit and the prevalence of prosthetic loosening was weak and not significant. No significant differences were found

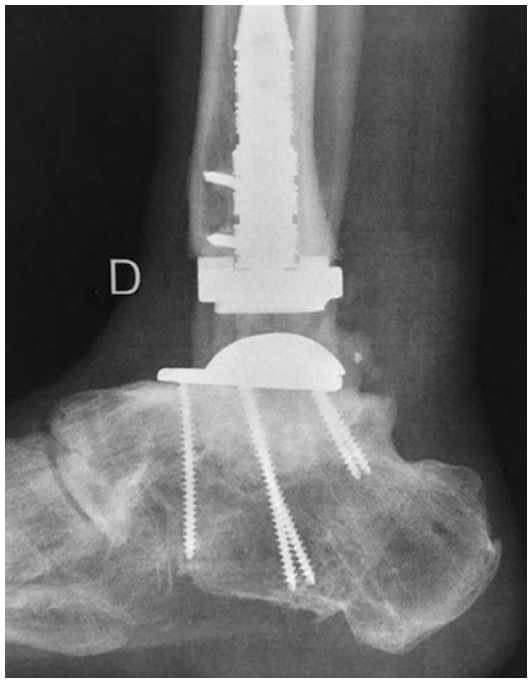

Fig. 15.4 Revision total ankle arthroplasty (RTAA): Invision talar component and INBONE II modular tibial stem

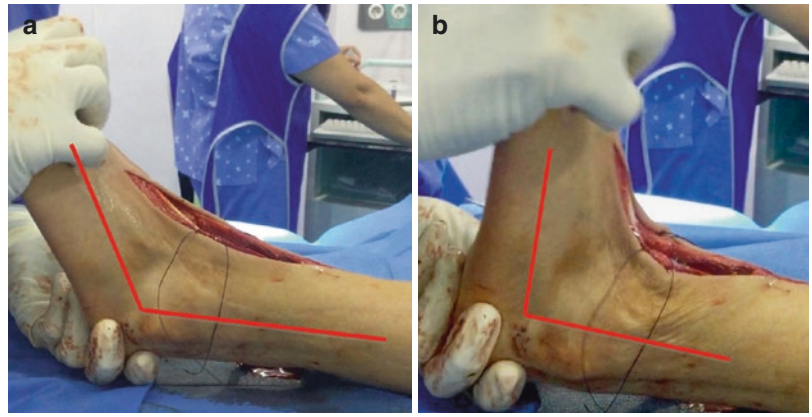

Fig. 15.5 Range of intraoperative mobility after revision total ankle arthroplasty (RTAA): (**a**) 30° of plantar flexion; (**b**) 13° of dorsal flexion. In the postoperative period, the range of motion achieved in the operating room tends to decrease

between the standard components and the revision components; however the custom-made components had slightly poorer results.

In the previous chapter, Horisberger et al. described a technique of bone supplementation in cases of revision of ankle prosthesis with large bone defects [11]. Their technique comprises two phases. First, remove the loosened components and reconstruct the tibial and talus bone defect with mono- or bicortical iliac crest autograft that stabilizes with compression screws or plates. In a second phase after 3–4 months and verification of the consolidation by CT, perform surgery for the implantation of a new prosthesis. No intraoperative or perioperative complications were observed, and there was no loosening of the components in the final assessment. Both the VAS and AOFAS scores improved significantly. However, the range of motion did not change after the revision.

Lachman et al. conclude in their recent publication that the results after arthroplasty of ankle prosthesis revision can be performed successfully in appropriately selected patients [12]. They observed a significant improvement in the functional and satisfaction scales. However, the maximum time for improvement is longer after a revision than after a primary prosthesis, and the magnitude of improvement will never reach the same levels as a primary prosthesis. The revision arthroplasty was a success in 89.6% (26 of 29 patients) with a reoperation rate of 20.7% and a prosthetic failure rate of 10.4% after a follow-up of 3.22 years. We have to evaluate each case individually to determine the best revision surgery in primary ankle prostheses that have failed. Table 15.2 summarizes the main results of RTAA in the literature.

Table 15.2 Main results and complications of revision total ankle arthroplasty (RTAA) in the literature

Authors	Year	Results	Complications	Comments
Ellington et al. [13]	2013	The mean radiographic measurements of component position did not change significantly postoperatively. The mean postoperative scores for the 34 patients with a retained TAA were 4.4 of 10 possible points on a VAS, 65 of 100 possible points on the AOFAS hindfoot scale, 93.5 of 100 possible points on the SF-12, 137.9 of 204 possible points on the Revised FFI-R, and 64 of 180 possible points on the AOS. The mean arc of motion radiographically was 18° preoperatively and 23° postoperatively, with all improvements occurring in plantar flexion	The RTAA was converted to an arthrodesis in 5 of the 41 patients, and 2 additional patients had undergone amputation. Some 22 patients (54%) had a subtalar arthrodesis performed at the time of the RTAA, with 19 of those having a custom-designed long-stem talar component placed simultaneously	These authors performed a review of 53 patients who underwent RTAA. The mean follow-up period was 49.1 months after the RTAA (minimum 2 years). The average time from primary Agility TAA to revision was 51 months. Forty-one of the 53 patients (77%) were available for follow-up. The most common indication for RTAA was talar subsidence (63%; 26 of 41). A lesser amount of preoperative talar subsidence was a significant predictor of a good outcome based on the AOFAS hindfoot score and the AOS score. The main conclusion was that RTAA may be considered an alternative to arthrodesis when treating patients with a failed Agility TAA

(continued)

Table 15.2 (continued)

Authors	Year	Results	Complications	Comments
Hintermann et al. [9]	2013	The estimated survival of the RTAAs at 9 years, with loosening of components as the end point, was 83%. The prevalence of component loosening was higher with the use of single-coated hydroxyapatite components (6 of 23 ankles, 26%) than with double-coated components (5 of 94 ankles, 5%)	Early complications included a fracture of the malleoli in two ankles and a dislocation of the polyethylene insert in one. Seventeen (15%) of the RTAAs required further revision surgery, in most cases for loosening of one or two of the prosthetic components	These authors performed 117 RTAAs (in 116 patients). Mean age, 55 years. Primary TAAs failed after a mean of 4.3 years and were revised with use of the HINTEGRA three-component TAA. The reason for revision involved the metallic components in 60 (51%) ankles, the bone in 28 (24%), the soft tissues in 20 (17%), and infection in 9 (8%). The talar component was revised in 104 (89%) ankles and the tibial component in 106 (91%).The medium-term results of RTAA after a failed TAA were similar to those after primary arthroplasty. The key to success was firm anchorage of the components to primary bone stock
Williams et al. [1]	2015	The Agility TAA lasted a mean of 6.7 years prior to revision to an INBONE II TAA	There were six intraoperative and five acute postoperative complications, leading to an overall 31.4% complication rate. There was one patient with continued pain postoperatively who underwent a second revision of the INBONE II 20 months postoperatively	A retrospective review of 35 cases of failed Agility TAA revised to an INBONE II TAA was performed. The average follow-up was 9.1 months. RTAA was a viable treatment option for failed TAA but with a high risk of perioperative complications
Pagenstert et al. [14]	2017	In all patients, significant pain relief was observed	In two patients a tibiotalocalcaneal arthrodesis was performed due to a painful aseptic loosening of RTAA	One-stage RTAA was performed on 14 patients, with a mean age of 52.7 years. The indication for revision surgery was aseptic loosening of one or both prosthesis components. The mean time between the initial TAA and revision surgery was 5.9 years
Lachman et al. [12]	2018	Improvements in PROs were better after primary than revision TAA. In this series, 10.3% of RTAAs required a second RTAA or arthrodesis surgery	Three (10.3%) RTAAs required further surgery; two required conversion to arthrodesis and one required a second RTAA	Some 15 (51.7%) patients underwent revision of just the talar and polyethylene components, while 13 (44.8%) patients underwent revision of all components. The most common cause was talar subsidence (51.7%). The average time to revision was 3.9 years, with a follow-up of 3.2 years after revision
Koo et al. [15]	2018	At 5 years, the outcomes for this design of TAA in this series were excellent, and were similar to those of previously published series from the design center	A total of three patients (four ankles) died and two (two ankles) were lost to follow-up. Three TAAs were revised for aseptic loosening (in two cases) or infection. Two further patients underwent reoperations, one for arthroscopic debridement of anterolateral synovitis and one for grafting of an asymptomatic tibial cyst	TAA was performed on 50 consecutive patients (55 ankles). With all-cause revision as an endpoint, implant survival was 93.3% at 5 to 10 years. If reoperations are included, this falls to 90.2% at 5 years. No other patient demonstrated radiographic evidence of loosening or subsidence. PROMs and satisfaction were excellent at latest follow-up

Table 15.2 (continued)

Authors	Year	Results	Complications	Comments
Clough et al. [16]	2019	The mean time to revision was 80 months (2 to 257). The mean AOFAS hindfoot score improved from 28 preoperatively to 61 at long-term follow-up	A total of 32 (16%) implants failed, requiring revision surgery	A total of 84 patients (87 ankles) were alive at the end of this study. Mean age: 54 years at the time of surgery. The implant survival at 15.8 years, using revision as an endpoint, was 76.16%. These authors found a steady but low decrease in survival over the study period

AOFAS American Orthopedic Foot and Ankle Society, *VAS* visual analog scale, *TAA* total ankle arthroplasty, *SF-12* short form 12, *FFI-R* foot function index, *AOS* ankle osteoarthritis scale, *RTAA* revision total ankle arthroplasty, *PROs* patient-reported outcomes, *PROMs* patient-reported outcome measures

15.4 Conclusions

The progressive increase in primary ankle prostheses implanted in recent decades has been accompanied by an increase in the rate of prosthetic revisions and greater study of the complications of this type of surgery and its results. Until now, ankle arthrodesis after prosthetic failure was the gold standard. However, the current results of prosthetic revision surgery are encouraging, given the results on the AOFAS, VAS, and SF-36 scales show significant improvement in all publications. However, these data do not mean that revision surgery is easy. Like all prosthetic revision surgeries, it comprises great complexity and requires knowledge and experience in prosthetic ankle implantation. The complications of revision surgery do not differ greatly from primary prosthetic surgery although we must pay close attention to those patients with risks prior to surgery. If a patient has a low bone mineral density, we should perform prophylactic stabilization of the malleoli. If the condition of the soft tissues is not optimal, care must be taken to monitor its evolution with correct presurgical preparation and adequate compressive bandages in the postoperative period. In this way we can avoid dehiscence or a torpid evolution of the soft parts that can evolve into deep infections. Finally, the rates of loosening and prosthetic failure can reach up to 15%–20% after revision surgery. To reduce these problems, we should look for tibial implants with greater diaphragmatic support with long tibial stems; at the talar level we should look for good bone support with a spongy autograft of the iliac crest and with flat talar components that provide a uniform distribution of the loads.

References

1. Williams JR, Wegner NJ, Sangeorzan BJ, Brage ME. Intraoperative and perioperative complications during revision arthroplasty for salvage of a failed total ankle arthroplasty. Foot Ankle Int. 2015;36:135–42.
2. Wooster BM, Grimm NL, DeOrio JK, Mithani SK. Iatrogenic Arteriovenous Fistula with associated pseudoaneuryms of posterior tibial artery after revision total ankle arthroplasty: a case report. J Foot Ankle Surg. 2017;56:75–7.
3. Glazebrook M, Arsenault K, Dunbar M. Evidence-based classification of complications in total ankle arthroplasty. Foot Ankle Int. 2009;30:945–9.
4. Gadd RJ, Barwick TW, Paling E, Davies MB, Blundell CM. Assessment of a three-grade classification of complications in total ankle replacement. Foot Ankle Int. 2014;35:434–7.
5. Roukis TS, Simonson DC. Incidence of complications during initial experience with revision of the Agility and Agility LP total ankle replacement systems: A single surgeon's learning curve experience. Clin Podiatr Med Surg. 2015;32:569–93.
6. Cody EA, Lachman JR, Gausden EB, Nunley JA 2nd, Easley ME. Lower bone density on preoperative computed tomography predicts periprosthetic fracture risk in total ankle arthroplasty. Foot Ankle Int. 2019;40(1):1–8.
7. Hsu AR, Franceschina D, Haddad SL. A novel method of postoperative wound care following total ankle arthroplasty. Foot Ankle Int. 2014;35:719–24.
8. Myerson MS, Aiyer AA, Ellington JK. Revision total ankle arthroplasty. JBJS essential surgical techniques. Based in original article. J Bone Joint Surg Am. 2013;95:2112–8.

9. Hintermann B, Zwicky L, Knupp M, Henninger HB, Barg A. HINTEGRA revision arthroplasty for failed total ankle prostheses. J Bone Joint Surg Am. 2013;95-A:1166–74.
10. Hordyk PJ, Fuerbringer BA, Roukis TS. Sagittal ankle and midfoot range of motion before and after revision total ankle replacement: a retrospective comparative analysis. J Foot Ankle Surg. 2018;57:521–6.
11. Horisberger M, Henninger HB, Valderrabano V, Barg A. Bone augmentation for revision total ankle arthroplasty with large bone defects. A technical note on 10 cases. Acta Orthop. 2015;86:412–4.
12. Lachman JR, Ramos JA, Adams SB, Nunley JA, Easley ME, DeOrio JK. Patient-reported outcomes before and after primary and revision total ankle arthroplasty. Foot Ankle Int. 2019;40(1):34–41.
13. Ellington JK, Gupta S, Myerson MS. Management of failures of total ankle replacement with the Agility total ankle arthroplasty. J Bone Joint Surg. 2013;95-A:2112–8.
14. Pagenstert G, Wimmer MD, Jacxsens M, Saltzman CL, Barg A. Aseptic loosening of total ankle replacement: one-stage revision ankle arthroplasty (Article in German). Oper Orthop Traumatol. 2017;29:220–35.
15. Koo K, Liddle AD, Pastides PS, Rosenfeld PF. The Salto total ankle arthroplasty—clinical and radiological outcomes at five years. Foot Ankle Surg. 2018. pii: S1268-7731(18)30131-0. https://doi.org/10.1016/j.fas.2018.04.003.
16. Clough T, Bodo K, Majeed H, Davenport J, Karski M. Survivorship and long-term outcome of a consecutive series of 200 Scandinavian Total Ankle Replacement (STAR) implants. Bone Joint J. 2019;101-B:47–54.