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Hip and Knee Section, Treatment, Surgical Technique: Proceedings of International Consensus on Orthopedic Infections

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Keywords

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Question 1: Does arthroscopic surgery have any role in the treatment of acute or chronic periprosthetic joint infection (PJI) of the knee or the hip?

Recommendation:

Arthroscopic surgery has no role in the treatment of acute or chronic PJI of the knee or hip.

Level of Evidence: Moderate

Delegate Vote: Agree: 93%, Disagree: 6%, Abstain: 1% (Super Majority, Strong Consensus)

Rationale:

Principles of managing periprosthetic joint infections (PJIs) include removal of infected soft tissue, bone, and biofilm containing implants. Advocates of debridement and implant retention, typically for acute infection, rely on sensitive antibiotics to the causative organism and its biofilm. In open debridement, antibiotics, and implant retention (DAIR), modular components are typically exchanged to improve access for thorough debridement and to reduce the biofilm volume.

Although arthroscopic surgery is attractive as a less invasive procedure than open debridement for the treatment of PJIs, it can be technically challenging to access all compartments of the joint to perform a proper debridement, risking partial surgical treatment. Partial surgical treatment risks failure to eradicate infection, side effects from long-term antibiotic use, and possible emergence of antibiotic resistance. Outcomes of staged revision following failed partial surgical treatment are worse [1,2]. The evidence for arthroscopic washout and debridement is predominantly small, noncomparative studies [3–10]. Comparative studies of DAIR comment that successful control of infection was lower if managed arthroscopically [1].

Success is typically viewed as long-term eradication of infection off antibiotics, but function must be maintained. Poor function can be caused by infection or from pain due to loose components, inflamed soft tissues, and wound management issues caused by sinus tract formation. Aggressive surgical management involving the excision of bone, soft tissue restraints, and removing well-fixed implants can challenge functional outcomes. Each individual PJI requires consideration of surgical aggressiveness to eradicate infection relative to maintaining function.

Arthroscopy in Total Knee Arthroplasty PJI

Arthroscopic treatment of total knee arthroplasty (TKA) PJI has variable success from 38% to 100%. Flood and Kolarik [3] were the first to describe successful arthroscopic treatment of 2 patients with a late acutely infected TKA. Waldman et al [4] reported that 6 of 16 patients (38%) with infected TKA who presented with less than 7 days of symptoms and who were treated with arthroscopic surgery retained their prostheses at a mean follow-up of 64 months. Dixon et al [5] reported that 9 of 15 patients (60%) with late acute infections of TKA retained their prostheses after a mean follow-up of 50 months. Chung et al [6] reported that 10 of 16 patients (62.5%) with late acutely infected TKA, who were treated with arthroscopic surgery within 72 hours of onset of symptoms retained their prostheses at a mean follow-up of 47 months. The 6 patients who failed arthroscopic debridement underwent successful infection eradication with open debridement with polyethylene insert exchange.

Ilahi et al [8] reported 5 patients with late acute TKA infections who were treated with arthroscopic surgery within 7 days of symptom onset; all patients retained their prostheses after a mean follow-up interval of 41 months. Liu et al [7] reported on 17 patients who had late TKA infections who were treated with arthroscopic debridement combined with a close continuous irrigation-suction system; at a mean follow-up 27.5 months, 15 (88%) retained their prostheses.

Byren et al [11] compared arthroscopic with open debridement in a retrospective review of 112 cases, 51 of which were of hips and 52 of which were of knees, to assess outcomes of patients treated for PJIs. The group found that the 15 patients with PJIs who were treated with arthroscopic washout had a significantly lower success (47%) than the 97 treated with open debridement (88%) (hazards ratio 4.2, 95% confidence interval 1.5–12.5, $P = .008$). Compared to the other series, the majority of the organisms were staphylococci and 77% were early postoperative within 90 days of the implantation.

Combining these papers results in 86 infected primary TKA treated with arthroscopic debridement. In total, 54 patients (63%) were successfully treated. The success rate was affected by the infecting organism which was available in only 71 cases. The organism results were as follows: Streptococcus 12/14 (86%), *Staphylococcus epidermidis* 11/16 (69%), *Staphylococcus* aureus 14/26 (54%), Gram-negative bacilli 3/6 (50%), Mycoplasma ½ (50%), no growth 5/6 (83%), and polymicrobial 0/1 (0%).

The time between implantation and infection was described in 60 patients. There were 8 (13%) postoperative infections using 6 weeks as a cut-off. Arthroscopic washout and debridement was successful in 4 (50%) cases. The remaining 52 cases were described as late acute PJI with success in 36 (69%) cases.

Arthroscopy in Total Hip Arthroplasty PJI

Only 2 studies investigated arthroscopy in total hip arthroplasty (THA) PJIs [9,10]. In a prospective study, Hyman et al [10] reported 8 consecutive patients who had late acute PJIs after primary THA, and were treated with arthroscopic surgery. Seven infections were caused by Streptococci and 1 by coagulase-negative *Staphylococcus*. After a mean follow-up of 70 months (range 29–104), there were no recurrent infections. The authors concluded that arthroscopic irrigation and debridement could benefit well-selected patients with late acute periprosthetic hip infections.

Another study included 2 patients with infected THA who were successfully treated with arthroscopic debridement followed by intravenous therapy; the report did not provide additional details [9].

Arthroscopy in Chronic Late Infections

The inclusion criteria for most of the studies mention a short duration between the presentation of symptoms and time of arthroscopic debridement, and therefore there is no clear evidence exploring the role of arthroscopy in chronic late infections. The 112 PJI series treated by DAIR included 35% that were over 90 days from the onset of symptoms to debridement, but this was a mixed series of predominantly open debridement with only 15 performed arthroscopically [11]. There was no subgroup analysis of the arthroscopic group available to make conclusions regarding timing or utility in treating chronic late infections.

There is a practical role of arthroscopy as part of the management of PJIs in chronic late infections. Arthroscopy can be part of the diagnostic workup of a painful arthroplasty allowing dynamic inspection of the components for instability and wear, ruling out noninfective causes, visualization of the synovium, and obtaining multiple samples for microbiology and histology. In patients who are not well due to sepsis, particularly where delaying surgery while waiting for appropriate equipment or surgical expertise risks further health deterioration, arthroscopically obtaining microbio-logical samples prior to commencing antibiotics and joint washout to reduce the bacterial load can allow time for appropriate preoperative planning for definitive surgical management of the PJI.

Conclusion

The studies describing arthroscopic management of PJIs generally analyze few patients, and have very specific inclusion criteria, making the data difficult to generalize. Combining the available studies, the success from acute late infection is approximately 60%. The only comparative series available concluded that arthroscopic debridement has a significantly lower success rate than open debridement. Future work could investigate specific bacterial infections that lack an ability to form a biofilm and are sensitive to long-term oral antibiotics that may be susceptible to more conservative surgical management. Overall, based on the current literature, we recommend against the routine use of arthroscopic surgery for the management of PJIs.

Question 2: Do all metallic implants need to be removed to eradicate periprosthetic joint infections (PJIs)? Does this apply to other metal hardware present (e.g. hook plates, cables) as well?

Recommendation:

Complete debridement of the hip or knee joint and removal of all hardware is ideal during surgical treatment of peri-prosthetic joint infections (PJIs). This principle should be followed whenever possible. However, there may be rare cases of PJIs when removal of all hardware may lead to marked morbidity and preclude future reconstruction. In the latter situation, some hardware may be retained.

Level of Evidence: Consensus

Delegate Vote: Agree: 97%, Disagree: 3%, Abstain: 0% (Unanimous, Strongest Consensus)

Rationale:

The treatment of periprosthetic joint infections (PJIs) involves the surgical removal of infected tissue and hardware in order to decrease the potential infectious bioburden. Many infecting organisms are capable of forming biofilms on foreign material surfaces. Therefore, all foreign materials, including bone cement and hardware, should be removed to better treat or control PJIs.

Retained hardware prior to total knee arthroplasty is a known risk factor for PJIs. In vitro studies demonstrate the ability of bacterial biofilms to adhere to orthopedic implants [12–14], and the presence of extravascular foreign bodies in animal models increases the threshold for infection to 100,000-fold due to a hypothesized granulocyte defect around implants [15,16]. Manrique et al [17] demonstrated a trend toward increasing rate of PJIs with partial or complete retention of hardware, but there was no statistical significance when compared to controls. There are limited reports highlighting the need to remove hardware from around the hip or knee in the setting of PJIs. Suzuki et al reported on their institutional experience of 2022 total knee arthroplasties. Seventeen infections were identified with a prior history of an open reduction internal fixation, and the presence of retained internal fixation material was correlated with postoperative infections [18]. However, the mere presence of prior fixation material cannot fully be separated from the increased risk of PJIs in a multiply operated joint.

Although the removal of all implant materials is thought to provide the greatest benefit, the degree of tissue or implant excision necessary for infection control is currently unknown. The inability to control infection in the setting of retained hardware is often thought to be due to residual bacteria. In manycases,the morbidity of removing implants or other hardware is considered too great, and, therefore, implants are retained. Evidence for this is supported in the practice of debridement with retention of components. Partial radical debridement has proven successful in small case series where 17 of 19 patients remained infection free with retained cemented or uncemented femoral pros-theses [19,20]. In addition to the retention of metal components, there are mixed results when considering cement retention. McDonald et al [21] reported that 3 of 7 patients with retained methyl methacrylate cement had a recurrence of infection, whereas only 8 of 75 patients in which the cement had been completely removed had recurrence of an infection ($P < .01$). There is evidence, however, that retaining cement that would otherwise be deleterious to remove is safe and effective in the setting of infection [22].

The retention of plates, hooks, or cables will often occur in the periprosthetic fracture setting. Evidence exists for successful fracture union with retained hardware in the setting of infection [23–25]. Berkes et al [23] demonstrated that 71% (86 of 121) successful fracture unions with operative debridement, retention of hardware, and culture-specific antibiotics and suppression. The retention of an intramedullary device, however, was associated with higher failure rates ($P < .01$). Rightmire et al [24] demonstrated a 68% (47 of 69 cases) success rate for hardware retention and debridement in the treatment of infected fractures. When considering these results, it is important to note the clinical differences between infected fractures and infected periprosthetic fractures that communicate with the joint space, which is typically a large effective space. In postoperative spine infections, Picada et al [26] reported on 24 of 26 fusions healing without removal of hardware, although they achieved these results most often with secondary closure.

When retaining components, rifampin should be considered as part of the antibiotic regimen, particularly for Staphylococcus infections. Zimmerli et al [16] conducted a randomized, placebo-controlled, double-blind trial and demonstrated a 12 of 12 (100%) infection control rate in the ciprofloxacin-rifampin group compared to the ciprofloxacin-placebo group (7 of 12, 58%) when implants were retained. Additionally, Trebse et al [20] demonstrated improved success rates with the addition of rifampin.

The removal of all infected materials, organic or inorganic, improves the ability to control PJIs by reducing bacterial bioburden and helping to eliminate biofilm. However, the removal of these materials must be balanced with the morbidity of their removal, and considered carefully in surgical planning.

Question 3: Should all knee compartments be resected during resection of an infected unicondylar knee arthroplasty (UKA)?

Recommendation:

Yes, during resection of an infected unicondylar knee arthroplasty (UKA), other compartments of the knee, including the fat pad, should also be resected.

Level of Evidence: Consensus

Delegate Vote: Agree: 80%, Disagree: 14%, Abstain: 6% (Super Majority, Strong Consensus)

Rationale:

Unicondylar knee arthroplasty (UKA) has become increasingly popular among those affected by single compartment osteoarthritis in that it preserves the integrity of the remaining knee compartments and ligaments, permitting the operated knee to be functionally and kinematically similar to the natural knee [27]. Similar to total knee arthroplasty (TKA), periprosthetic joint infections (PJIs) after UKAs can occur with reported rates ranging from 0.2% to 3% [28,29].

There is surprisingly minimal literature regarding the treatment and outcomes of PJIs after UKA. For chronic PJIs, Labruyère et al [28] demonstrated 100% survivorship in a series of 9 infected UKAs treated with 1-stage exchange arthroplasty to a TKA at a median of 60 months, 5 of which were initially unsuccessfully treated with synovectomy, joint lavage, and antibiotics. The authors also noted that wedges (n = 6) and stems (n = 5) were required in the majority of patients. Böhm et al [30] performed exchange arthroplasty in 2 cases of PJI with one resulting in a femoral amputation. One study revised 2 cases via a second, single-stage UKA in conjunction with synovectomy and prolonged antibiotic therapy, with the new implants being the same size as the initial implant, and with one implant being cemented with antibiotic cement, while the other case did not have a cemented implant [31]. Four studies revised 9 knees to a TKA [32–35], with one study having 2 re-revisions following initial resection for recurrent infection [35]. Furthermore, Hamilton et al [36] performed 3 two-stage exchange arthroplasties, with one initially undergoing irrigation and debridement but ultimately requiring revision to a TKA via a 2-stage exchange arthroplasty for recurrent infection.

Three studies successfully treated deep infection following UKA with retention of the implant with the first reporting 1 case treated with debridement and inlay exchange [34], the second reporting 2 cases treated with washout, debridement, and bearing/liner change[35], and the third reporting 1 case treated with synovectomy and placement of gentamicin chains [37].

It is clear through the current literature that there are several viable options to treat infections following UKAs. The method that the surgeon chooses to use should be selected based on the severity and chronicity of infection as well as the amount of remaining native bone and cartilage. Bone loss is also not uncommon in the setting of infection [31]. In acute infection and in the absence of involvement of other compartments, debridement and retention may be a reasonable option. In patients with bone loss, chronic infections, or with infections that may be difficult to eradicate due to a resistant or challenging organism, a 1-stage exchange or 2-stage exchange arthroplasty to a UKA or TKA may be performed with the inclusion of a wedge or stem as indicated. If 2-stage exchange arthroplasty is being performed, during resection arthroplasty other compartments and the fat pad should also be resected as they may harbor bacteria. This practice also allows for insertion of a proper spacer.

Question 4: Can sub-radical resection arthroplasty (leaving parts of implants in place) be considered during management of patients with chronic periprosthetic joint infections (PJIs)?

Recommendation:

Sub-radical resection arthroplasty (leaving parts of implants in place) may be considered during management of patients with chronic PJIs when a component is proven to be well-fixed, and its removal precludes opportunity for future reconstruction.

Level of Evidence: Limited

Delegate Vote: Agree: 68%, Disagree: 29%, Abstain: 3% (Super Majority, Weak Consensus)

Rationale:

Two-stage revision with removal of all prostheses followed by reimplantation has been considered the gold standard to treat chronic periprosthetic joint infections (PJIs) [22,38,39]. However, the removal process might necessitate the use of additional procedures such as an extended trochanteric osteotomy to perform the removal of a well-fixed stem [40]. This can result in severe compromise of the proximal femur and jeopardize future fixation of a reimplanted stem. Retaining a well-fixed stem or acetabular component can be an option to avoid this in the setting of PJI treatment.

Struhl et al [41] initially described this technique in 1989. In his case study, a 47-year-old man with a *Staphylococcus epidermidis* infection was treated by removal of the bipolar head, irrigation and debridement, retention of the femoral component, and placement of antibiotic-impregnated beads. After 7 weeks of intravenous antibiotic therapy, the patient underwent reim-plantation of the acetabular component with an uncemented device. At 18-month follow-up, the patient had fully recovered without evidence of infection. In 2013, Lee et al [42] reported the results of 17 two-stage reconstructions retaining well-fixed cementless femoral stems in the treatment of PJI. At 2-year to 8-year follow-up, 15 patients (88%) had no recurrence of infection and had satisfactory radiological and clinical outcomes. More recently, Ekpo et al [19] reported on 19 patients with chronic infection whose femoral component was considered to be well fixed and its removal would result in a marked femoral bone loss. Only 2 patients (11%), who additionally had failed a prior 2-stage exchange, failed secondary to recurrence of infection at a minimum of 2-year follow-up. Two more recent publications have looked at the results of this procedure with longer follow-up periods [43,44]. In a study by El-Husseiny and Haddad [43], 18 patients who had partial component retention were evaluated. These were carefully selected cases out of all the 293 patients who were surgically treated for PJIs at their institution. The selection criteria and indications for this approach were those who had complex total hip arthroplasties with ingrown femoral stems or complex acetabular components that were well fixed [43]. Their reported success rate was 83%. Also, Ji et al [44] retrospectively analyzed 31 patients. In his series, patients underwent retention of components in what they called partial single-stage revision. Either the acetabular or femoral component was retained given that there was evidence of good fixation. Of the 31 patients, 27 were considered to have a good outcome(87.1%) at latest follow-up.

Results of subradical resection arthroplasty have shown acceptable success rates ranging from 87% to 89%. These can be compared to published results of 2-stage results, although there is a high variability of reported success rates [45–47]. Only one study reports on 1-stage subradical resection and retention of well-fixed components with promising success rates of 87% [44]. We consider that a careful selection of patients with adequate evaluation of fixation is the key to determine if retention of components is a viable option. Although there is a lack of strong evidence, a partial exchange may present a better alternative than complete resection performed in 2-stage revision of chronic PJIs when the stem is well-fixed with bone ingrown stability. We, therefore, support the use of partial exchange in the treatment of chronic PJIs in selected cases.

Question 5: Is it possible to have an isolated infection of only a portion of the joint (for example the femur and not the acetabulum or tibia and not the femur)?

Recommendation:

Unknown. Infection of a prosthetic joint is likely to involve biofilm formation on surfaces of all foreign material. However, there may be rare circumstances when infective organisms may not be able to reach the surface of a well-fixed implant and form a biofilm.

Level of Evidence: Limited.

Delegate Vote: Agree: 75%, Disagree: 19%, Abstain: 6% (Super Majority, Strong Consensus)

Rationale:

Using a standardized study search protocol, we performed a comprehensive review and analysis of the literature related to this subject matter. There were no specific studies examining the issue of partial infection of an implant. As a proxy, we examined the literature related to the outcome of surgical treatment of chronic periprosthetic joint infections (PJIs), when partial retention of an implant was deemed appropriate. The primary outcome measure was success of treatment, at a minimum of 2 years, defined as infection-free retention of the implant. The search strategy and inclusion criteria were chronic PJI, total hip arthroplasty, total knee arthroplasty, and partial retention. Subsequently, our search strategy yielded 9 articles for analysis, including 130 revisions (Table 1). The follow-up period was 2–8 years (mean 4.1 years) or less if failure occurred. We also recorded the types of bacteria and the success rates reported in each study.

There were no studies related to partial retention of total knee arthroplasty components. The overall success rates of eradication of infection ranged from 80% to 100% (mean 90%). There were 113 acetabulum-only revisions and 17 femur-only revisions. There were 11 failures in the acetabulum-only group(9.7%) and 2 failures in the femur-only group (11.7%). There was no statistically significant difference between the groups. The offending bacteria in the studies are similar to what is expected to be seen in PJIs.

Conclusions

Given that in hip and knee arthroplasty the surfaces of prosthetic material are in contact with bone and knowing the fact that infective organisms are capable of attaching to foreign material surfaces and forming biofilms, we are inclined to believe that partial infection of a prosthesis does not exist. Infective organisms are capable of accessing the effective joint space in the hip and the knee and infecting the entire prosthesis. However, there may be rare circumstances when an implant is well-fixed, either by cement or through osseointegration, and the infective agents are not able to access the prosthesis-bone interface. There were no studies to prove or disprove this assumption. If such a situation existed, then a resolute approach for radical resection of all implants could plausibly lead to an overtreatment and unnecessary morbidity.

Based on the scant data available, it appears that partial retention of well-fixed implants in patients with reconstructive challenges may be a viable option. Such surgical options should only be reserved for patients in whom removal of well-fixed implants is likely to compromise or prevent a later reconstruction. The basic principles of aggressive soft tissue debridement and complete removal of infected implants should still be obeyed for the majority of patients.

Question 6: Should heterotopic ossification (HO) be removed during resection arthroplasty of an infected prosthetic joint?

Recommendation:

We recommend that surgeons give strong consideration to removal of accessible heterotopic ossification (HO) in an infected prosthetic joint that will not compromise future reconstruction.

Level of Evidence: Consensus

Delegate Vote: Agree: 80%, Disagree: 10%, Abstain: 10% (Super Majority, Strong Consensus)

Rationale:

Heterotopic ossification (HO) is the presence of bone in soft tissue where bone does not normally exist. Several risk factors have been associated with HO such as spinal cord injury, head injury, neurologic disorders, osteoarthritis, male gender, burns, other trauma with severe soft tissue damage, and joint arthroplasty. The presence of HO at an infected prosthetic joint may be encountered during the time of resection arthroplasty. HO should be removed if present within the infected area, if it interferes with adequate exposure and debridement, or when it could potentially interfere with function after resection arthroplasty. Following surgical resection of the heterotopic bone, beneficial effects on the range of motion and pain relief have been described. However, there are still controversies about the optimal timing for surgical resection.

A perioperative regimen is crucial for recurrent prophylaxis. Nonsteroidal anti-inflammatory medications and radiotherapy have demonstrated beneficial effects on HO prophylaxis with low recurrence rates for a number of indications such as total hip arthroplasty and acetabular surgery. Resection arthroplasty is an effective modality to treat hip arthroplasty infections with HO. If subsequently the patient develops HO while he or she is mobilized, it may facilitate walking on that hip [53].

However, in an extensive search of the English literature we were unable to find any relevant studies that investigate the effect of resection of HO at the time of resection arthroplasty on surgical outcomes.

Question 7: When soft tissue coverage requires a reconstructive flap, can it be performed at the time of explant or should it be deferred until reimplantation?

Recommendation:

When a soft tissue defect requires a reconstructive flap, it is safe to perform flap coverage at the time of explant or at the time of reimplantation. Early flap coverage at the time of explantation improves soft tissue biology for eradication of infection and allows for earlier mobilization following reimplantation given greater flap maturity.

Level of Evidence: Consensus

Delegate Vote: Agree: 95%, Disagree: 2%, Abstain: 3% (Unanimous, Strongest Consensus)

Rationale:

No prospective comparative studies were identified which compared patient groups who have had soft tissue reconstruction flaps performed at the time of explant vs at the time of reimplantation. Much of the literature pertinent to this question comprises heterogeneous series of patients who have exposed or infected total knee arthroplasty (TKA) implants. For TKA soft tissue defects, medial gastrocnemius rotational flaps were most commonly reported. However, many additional rotational and free flaps have been described: lateral gastrocnemius, latissimus dorsi, local fasciocutaneous, quadriceps advancement, sartorius, and rectus abdominis.

Tetreault et al [54] published the only study identified which evaluated patients based on the timing of flap coverage. Treatment was based on surgeon opinion of insufficient soft tissues. The cohort was heterogeneous, including patients who received medial gastrocnemius flaps at the time of explantation, repeat spacer, reimplantation, or irrigation and debridement with liner exchange. There was a nonsignificant trend toward higher failure rates when the flap was performed with spacer implantation (first or repeat) compared to definitive implants (reimplantation or retention with liner exchange). The overall reinfection rate among all groups was 52% at 4 years. Selection bias likely impacted these results and the authors clearly state that flap timing was based on necessity, rather than a belief that the timing was advantageous.

Corten et al [55] and Young et al [56] described standardized staged protocols for the management of infected or exposed TKA implants, including soft tissue coverage at the time of explantation, with disparate results. Although Corten et al report 92% flap survival and one case of reinfection, patients in Young's series had a 29% amputation rate. Ries and Bozic [57] described a mixed cohort, which included 7 patients who underwent soft tissue coverage at the time of spacer insertion. Four patients were treated successfully, while 1 flap failed and 2 went on to recurrent infection. Gerwin et al [58] and Browne et al [59] used flaps between revision stages and at the time of repeat spacer, respectively. Both series reported relative success, with 83% and 78% successful reimplantations, respectively.

McPherson et al [60] reported on the only identified cohort of staged revision with flap during reimplantation. They described 5% recurrent infections and 33% wound complications among 21 patients.

Based on these published reports, there is limited evidence to support soft tissue flap reconstruction at the time of implant removal and antibiotic cement spacer insertion. In contrast, a small body of literature appears to support deferral of soft tissue coverage until reimplantation of a revision implant. However, these patient populations are not necessarily comparable within the limited body of evidence available. Most studies report high rates of complications, including recurrent infection, recurrent soft tissue defects, and subsequent limb loss, highlighting the difficulty of this clinical problem regardless of treatment approach. Based on this literature as well as experience, we prefer the former approach, given the benefits of improved soft tissue coverage and biology to the eradication of infection. Furthermore, performance of flap coverage at the time of explantation allows for unrestricted rehabilitation following later reimplantation.

Of note, numerous older studies were identified which describe the usage of soft tissue flaps to facilitate implant retention; however, this approach is not considered consistent with modern, evidence-based management of exposed, infected arthroplasty implants.

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Table 1

List of Publications.

Author	Year	Journal	Study Period	Country	Population Size
Faroug et al [48]	2009	*Hip International*	2004–2009	United Kingdom	2
Anagnostakos et al [49]	2010	*Hip International*	1999–2008	Germany	12
Lee et al [42]	2013	*Acta Orthopaedica*	2005–2010	South Korea	19
Ekpo et al [19]	2013	*Clinical Orthopaedics and Related Research*	2000–2011	USA	19
Lombardi et al [50]	2014	*Bone and Joint*	2011	USA	7
Fukui et al [51]	2015	*Journal of Orthopaedics*	2009–2014	Japan	5
El-Husseiny and Haddad [43]	2016	*Clinical Orthopaedics and Related Research*	2000–2010	United Kingdom	18
Ji et al [44]	2016	*International Orthopaedics*	2000–2013	China	31
Chen et al [52]	2017	*International Orthopaedics*	2004–2013	China	16