Uncemented Revision Total Knee Arthroplasty for Peri-prosthetic Joint Infection

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Rhidian Morgan-Jones

Abstract

Uncemented fixation in revision total knee arthroplasty for peri-prosthetic infection is discussed by covering several key issues. Firstly, what is and how to undertake a systematic and effective debridement. Secondly, reviewing the concept of zonal reconstruction and fixation, looking at the options for dealing with bone loss. Finally, a discussion of the role of antibiotics and published outcomes.

Keywords

Debridement • Uncemented revision knee arthroplasty • Zonal fixation • Antibiotic delivery

Introduction

De-bride-ment is the surgical removal of foreign matter and dead tissue from a wound. It derives from the original French debridement (1835–1845), equivalent to debride, literally to take away the bridle. In modern management of orthopaedic infection we must understand what debridement involves and have reproducible steps that can be applied to each anatomical region. Here we will discuss debridement as it applies to revision of infected total knee replacement. Its importance cannot be overstated, as the commonest cause of re-revision is infection, between 30 and 50 % in one series [1]. Once debridement has been completed thoroughly, reconstruction and fixation should proceed by the surgeons chosen method, with cemented or uncemented fixation being unimportant provided it is methodically done, using and respecting the remaining bone stock and a multi-zone strategy [2–5]. In this chapter we will cover debridement, reconstruction and fixation, antibiotic delivery and finally outcome in the infected knee arthroplasty using uncemented techniques.

Debridement

Extensile Approach

Debridement begins with an extensile approach to the infected knee, and must consider the

R. Morgan-Jones, MBBCh, MMedSci, FRCS(Ed/Tr&Orth)
Department of Trauma and Orthopaedics, University Hospital of Wales, Cardiff, Wales, UK
e-mail: rhidianmj@hotmail.com

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previous skin incision or incisions. As a general rule, use the previous incision if adequate and extend proximally and distally as needed. Be prepared to excise broad scars in a mobile joint, but proceed with caution in the stiff and tethered knee. Sinuses in the line of incision can be excised, elsewhere isolated sinuses can be curetted and the deep sinus tract excised. All curetted sinuses will heal if the infected source is removed and debrided adequately. Occasionally, the need for plastic surgical coverage must be planned for when potential non-viable or necrotic skin loss is present, a medial Gastocnemius rotational or pedicled flap is generally sufficient. The author favours a tibial crest osteotomy to improve access to both explant and debride all corners, whilst protecting the extensor mechanism.

Methods of Debridement [6–8]

Debridement can be divided into superficial and deep. Superficial wound debridement can be subdivided into *autolytic,* which includes hydrogels and auto-enzymes; *enzymatic,* which includes streptokinase and collagenase; and *biological,* which includes maggot therapy.

Deep wound debridement can similarly be sub-divided into *surgical,* which includes explantation and sharp dissection; *mechanical,* including curettage and reaming, power lavage and H_2O_2 [9]; and *chemical,* which can include acetic acid [10] and honey [11, 12].

It is with deep debridement we should concentrate when discussing the management of the infected knee replacement. However, we should always consider the soft tissue envelope, as failure to do so may lead to poor wound healing and subsequent compromise of deep tissues [13, 14].

Surgical Debridement

Explantation when dealing with infected arthroplasty is akin to sequestrectomy and must include all implants and necrotic bone. Sharp dissection involves a thorough synovectomy and excision of all visible infected membrane/biofilm. Only when explantation and sharp dissection have been completed can the next stage of debridement begin.

Mechanical Debridement

Mechanical debridement has several distinct stages. The femoral and tibial joint surfaces and intra-medullary canals are curetted of any residual membrane, avascular bone and cement residue. Once complete the femoral and tibial intra-medullary canals are reamed under power to remove persistent neo-cortex and membrane in a compartmental debridement as described by Prof. Charles Lautenbach [15–18] from Johannesburg, South Africa. Once complete, all joint surfaces and canals are lavaged under power. Pulse lavage has a tidal effect of washing loose debris away from the operating field but more importantly lavage under power makes any infected, membrane adherent to bone, oedematous. Oedematous membrane is easier to both see and to debride by a further pass of curettage and reaming. Mechanical debridement should be seen as cyclical, with a minimum of two and possibly three cycles required to adequately debride. The volume of power lavage is less important than where and how the operative field is lavaged. Lavage of the soft tissues, joint surfaces and the intra-medullary canals must be performed in sequence. Most surgeons prefer normal saline, but other solutions with added chemicals or antibiotics can be used as the surgeon prefers.

H_2O_2 has been used for the mechanical effect of O_2 release producing effervescent cleaning and theoretically degrading biofilm and penetrating the cell wall. Controversy remains over the risk of air embolus whilst using H_2O_2, although this is mitigated by the use of a tourniquet. If H_2O_2 is used, it would make sense to use it after cyclical mechanical debridement with curettage, reaming and power lavage, to create biofilm and organisms susceptible to chemical debridement.

Chemical Debridement

Chemical debridement is the final part of deep debridement and seeks to create a hostile chemical environment that further degrades residual biofilm, kills bacteria and prevents future bacterial growth. Several options are available, the author prefers 3 % Acetic Acid [19] which lowers the environmental pH and has both Gram −ve and +ve activity. Generally a 10 min acetic acid soak before reimplantion is sufficient. Another option is SurgiHoney™ [11, 12] which works by a local osmolar effect but also produces H_2O_2. SurgiHoney also has the potential to be used as an antibacterial coating after re-implantation. Other potential chemical debriding agents include alcoholic betadine/chlorhexidine and hypochlorite.

Zonal Fixation and Reconstruction [2]

Solid fixation of the implant is important for long-term survival but also early on for immediate rehabilitation and function, and is irrespective of whether uncemented or cemented techniques are used. The larger the bone defect the more difficult the fixation. Three zones of fixation exist: the joint surface or epiphysis (zone 1), the metaphysis (zone 2) and the diaphysis (zone 3). In most revision knee replacements, zone 1 is compromised and therefore the zones 2 and 3 need to be used. The concept of zonal fixation and reconstruction is applicable to both tibia and femur (Figs. 21.1 and 21.2).

Fixation in Zone 1: The Epiphysis (Joint Surface)

In most revisions and all re-revisions, zone 1 is compromised by implant failure and removal. To enhance the use of fixation in zone 1, it is necessary to establish a stable surface, free of cement debris, avascular bone and fibrous membrane. Where possible, flat aligned cuts with augmentation of defects aides implant stability and fixation. Augmentation can be by cement, bone graft or metal block but in zone 1 fixation can only be reliably achieved with PMMA cement. As a rule, where augmentation is needed, fixation in at least

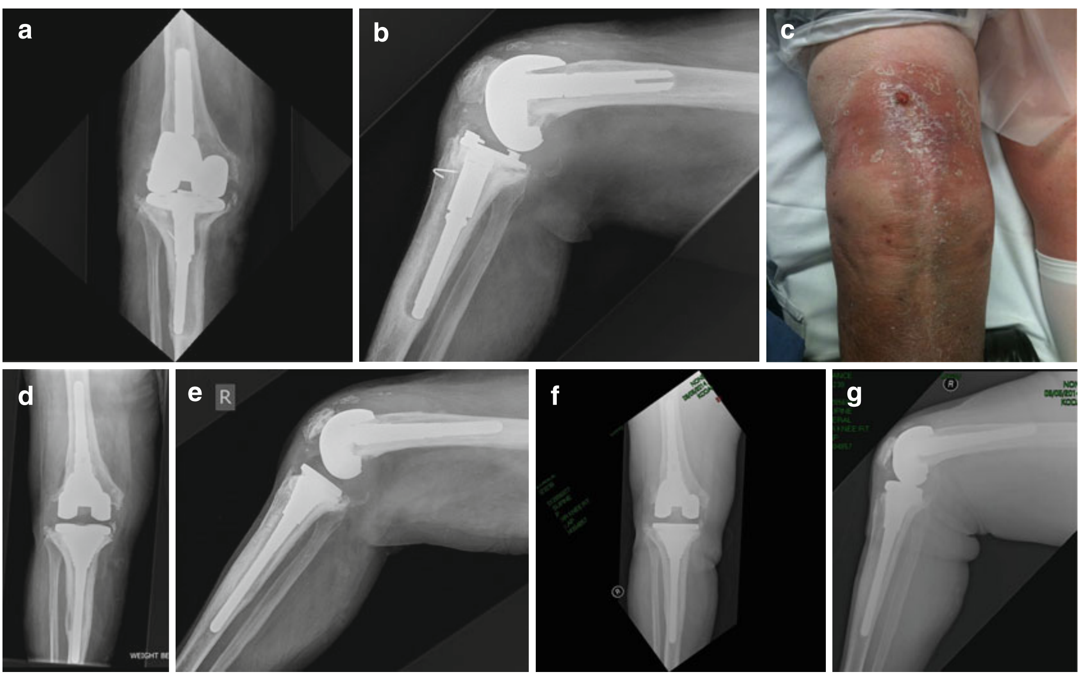
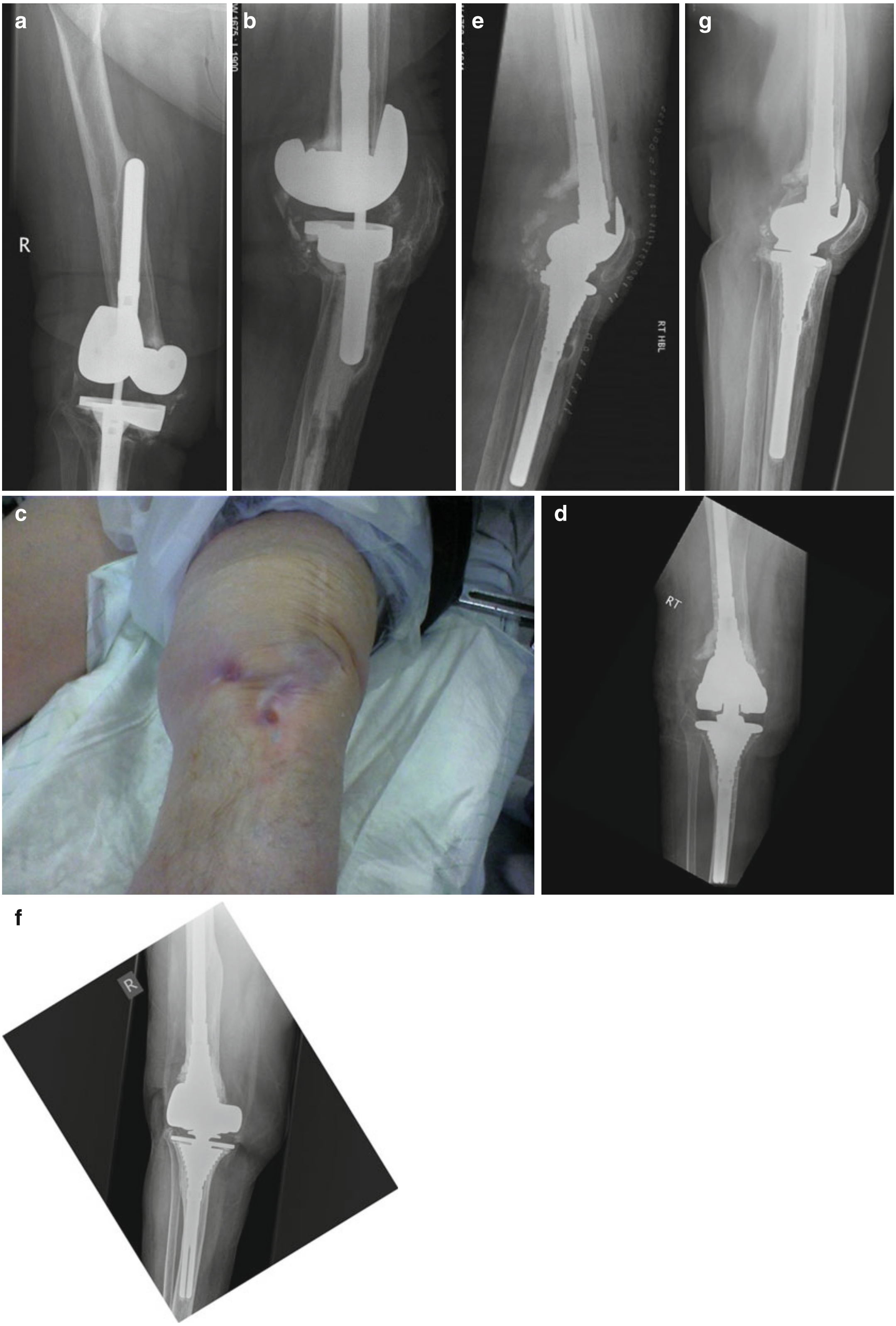


Fig. 21.1 (**a**, **b**) An infected, loose revision TKA 18 months post two-stage revision. (**c**) Clinical photograph of draining sinus and inflamed soft tissue envelope. (**d**, **e**) X-rays post one-stage revision using uncemented fixation with metaphyseal sleeves in zone 2 and diaphyseal stem in zone 3. (**f**, **g**) X-rays at 3 year review showing fixation and physiological loading leading to femoral and tibial bone remodelling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1 other zone is necessary. Offset stems allow zones 1 and 3 to be linked. The geometry of the diaphysis and that of the epiphysis are not congruent, therefore an offset is sometimes needed to optimize zone 1 coverage and avoid medial overhang of the tray.

Fixation in Zone 2: The Metaphysis

Since Julius Wolff described the law which bears his name in 1892 [20, 21], we know that bone reacts to loading with increased bone density and when unloaded, bone will be reabsorbed. Traditional revision knee replacement systems bypass the metaphysis concentrating on diaphyseal and joint surface (zones 3 and 1) fixation. However, fixation in the metaphysis (zone 2) allows fixation closer to the point of articulation and makes restoration of the joint line easier. The geometry of the metaphysis and that of the joint surface are similar therefore obviating the need for an offset on the tibial implant. Similarly, fixation in zone 2 allows posterior translation of the femoral component and the use of shorter stems, to mitigate against femoral bowing which moves implants anteriorly. Failure to utilise zone 2 can lead to uncontrolled biomechanical sheer stress and instability of augment fixation in zone 1 potentially leading to early failure of the revision [22–24].

There are currently only two options for direct fixation in zone 2, cement [25] or metaphyseal sleeves (DePuy-Synthes) [26, 27]. Cement fixation in metaphyseal bone is not costly, readily available and can be used with either cemented or uncemented stems. Metaphyseal sleeves have been available since 1975 but have been most widely used as part of the S-ROM Noiles, rotating hinge system which has shown good mid-term results [26]. Metaphyseal sleeve fixation optimises load transfer to improve bone regrowth ('Wolff's law') and on-growth [27]. Fixation closer to the joint space provides better restoration of joint line and axial/rotational fixation stability even in the presence of cortical or cancellous bone defects and are an alternative to long stems [28, 29]. Metaphyseal sleeves as part of mobile bearing revision systems have been available for over 30 years but have only belatedly gained popularity, showing good early to mid-term results [4, 30, 31]. If zone 1 is sufficiently preserved to accept a worthwhile cement mantle, additional fixation in zone 3 might not be necessary. However, insufficient data on stemless metaphyseal sleeve fixation exist for general use to be recommended.

Metaphyseal sleeves are the only method available that provides both bone reconstruction and direct implant fixation. Indirect metaphyseal fixation in zone 2 is possible when reconstruction has been achieved first. As with zone 1 augmentation, zone 2 reconstruction can be achieved with cement, bone graft (bulk allograft or morsellised impaction graft) [32] or by the use of trabecular metal (TM) cones (Zimmer) which acts as metal bone graft and is used as a reconstruction ring. Trabecular metal has a structure similar to cancellous bone, is highly biocompatible and osteoconductive [33, 34]. Once metaphyseal reconstruction is secure and stable, secondary zone 2 fixation is achieved with bone cement. Trabecular metal cones offer the advantages of availability and intra-operative press-fit stability, allowing immediate weight bearing [35, 36]. Bone ingrowth has been demonstrated even in tibial TM retrieval specimens revised for infection [37]. Zone 2 reconstruction, however achieved, should be supported by secure zone 3 fixation with either cemented or uncemented stems.

Fig. 21.2 (**a**, **b**) Chronically infected revision TKR with massive bone loss. AORI classification grade 3 femur and tibia. (**c**) Clinical image of multiple sinuses draining chronically infected revision knee arthroplasty. (**d**, **e**) Post-operative x-rays after 1-stage revision using uncemented fixation: zone 2 metaphyseal sleeve, zone 3 diaphyseal stem. (**f**, **g**) Four-year review showing fixation and physiological loading leading to femoral and tibial bone regeneration

Fixation in Zone 3: The Diaphysis

Fixation in zone 3 by diaphyseal stems have been shown to offload the metaphysis where augmentation may have been necessary thus protecting the implant/cement interface areas from failure. Stems may be cemented or uncemented, both can offer long-term survival but both have individual limitations. In cemented stem fixation, bone resorption occurs in the metaphysis over time [38]. Using cementless stems seems to be beneficial for the bone of the metaphysis [39].

The geometry of the diaphysis and that of the epiphysis is not congruent, therefore an offset is occasionally needed. With this concept an optimized coverage of the joint surface can be assured. However it is still unclear whether a cemented or an uncemented fixation of the stems is advantageous and optimal length as well as optimal thickness of the stems are also still unclear [40]. Cementless diaphyseal engaging stems have been reported with lower radiographic failure than cemented stems in two-stage re-implantation, with similar re-infection rates despite the absence of antibiotic cement in cementless construct [5].

Treatment Options

Management options are based on the severity of defect and the chosen method of bone reconstruction, which range from bone cement, allograft, metal augmentation, and mega prosthesis. Recently, new alloys with high porosity have been introduced with satisfactory short-term results [41, 42]; however, it should be recognised that all methods of managing bone loss have different pros and cons [43]. Selection of the best treatment method is based on many factors, including defect size and location, the patient's age and health, and ability to participate in the necessary postoperative rehabilitation. Metaphyseal sleeves and porous tantalum cones are a major addition in dealing with large, central, contained and uncontained defects. The use of stem extensions in cases of bone deficits is helpful in enhancing fixation and lessening stresses to weakened condylar bone [44].

Cement Augmentation

This has limited clinical use and is indicated for small defects that are 5–10 mm. The advantages of cement are economical (affordable) and universal availability. The disadvantages include difficulty with uncontained defects, early radiolucent lines due to poor fixation and a failure to reconstitute bone for future surgery. However, in the elderly, low-demand patients and for expediency there remains a role for cement augmentation. Cement augmentation has been combined with metallic screw secured into the bone cortex as a reinforced hybrid construct [45] but this has not found widespread or sustained clinical use.

Bone Graft

When bone grafting, the host bone must be debrided to a viable layer and well cleaned. The graft must be contained and/or compressed, and preferably both. The aim, whenever possible, is to produce graft that has inherent structural stability although it always needs protecting with stems. High complications rates have been reported which include graft-host non-union, aseptic loosening, peri-prosthetic fractures, infections, and implant instability [46]. Allografts have several advantages. They are versatile and can be contoured to fill any shape and size (bulk or morsellised impaction grafts). Bone graft has the potential to restore bone stock provided that incorporation occurs, although this is always unpredictable [47, 48].

Disadvantages, however, are many. Excellent load transfer with bulk graft is seen, although this may lead to collapse unless revascularisation and incorporation occur. Outcome is technique and surgeon dependant and remains biologically unpredictable. In many countries and institutions the supply is limited and expensive. The risk of disease transmission is a real but statistically a minor concern. Failure to re-vascularise and incorporate will give an on-going risk of non-union and collapse. However, acceptable mid-term results have been published by several authors for both massive allografts [49] and impaction bone grafting [50]. Other reports have been less favourable for both [51–54]. The risk of infection is minimised by the use of antibiotic coated cancellous allograft [55–57].

Autograft have some advantage over allograft. It is more biologically active and carries no risk of disease transmission, and contouring is easy with a lower risk of non-union. The disadvantages, however, are a limited supply and provide only small bulk and limited morcellised graft. Autografts are usually only appropriate for complex primary TKR. Bone substitutes are commercially available with both osteoconductive and osteoinductive properties. They are presented in various consistencies such as putties, pastes, injections. There are, however, major disadvantages of significant cost, uncertain integration and a lack of structural options.

In summary, bone grafting has a place in revision TKR in the chronologically and physiologically young patients to increase bone stock. It offers versatility for differing types of bone loss. Allograft offers bulk for large bone loss, whilst allograft, autograft or bone substitutes may be appropriate for smaller defects.

Prosthetic Augmentation

Most modern revision systems include a complete set of metallic augments and stems. These are designed to reconstruct in zone 1 (joint surface) and zone 2 (metaphysis) and support in zone 3 (diaphysis).

Metal augments have the advantages of availability with no risk of disease transmission, shrinkage or collapse. They offer good load transfer and cutting guides increase ease and accuracy of use. The disadvantages include limited sizes and shapes producing further host bone loss. Augmentation usually necessitates the need for diaphyseal stem fixation. Metal augments may be a poor choice in massive defects, modularity may increase debris and reconstruction without use of metaphyseal and diaphyseal bone may lead to early failure [2]. The role of cemented and uncemented stems continues to be debated but the use of both can be supported [58–62].

The new generation of metaphyseal implants have made a dramatic difference to bone reconstruction. The commonest options include metaphyseal sleeves (DePuy-Synthes) [2, 4] or porous reconstruction cones (Zimmer) [63, 64]. Trabecular metal cones have shown good radiographic osteo-integration at 1 year, mitigating against future collapse or implant migration [65]. Metaphyseal sleeves have a pedigree of over 30 years of biological fixation allowing physiological loading to help regenerate bone stock and secure long-term fixation [4, 27–31, 66–69].

In summary, metal augments are versatile and allow intra-operative customisation and are suitable for moderate-sized, non-contained defects. Tantalum cones allow reconstruction of massive zone 2 defects with predictable osseo-integration and secure cement implant fixation. Metaphyseal sleeves offer an excellent option for reconstruction using zone 2 uncemented fixation irrespective of contained or uncontained defects. They offer immediate fixation and reconstruction and obviate the need for bone graft.

Are Antibiotics Important?

Debridement is the key to infection clearance. The more difficult question is what role antibiotics play in the eradication and prevention of recurrence. For eradication, antibiotics can be seen as adjunctive to surgery, treating the soft tissue envelope and attacking residual organisms. For this, antibiotics should be at bactericidal levels throughout the surgical period. For prevention of implant contamination/infection, antibiotics should prevent the establishment of a biofilm and must therefore be used for a sufficient time postoperatively. The time frame for antibiotics post revision can vary from a 2 weeks to 6 months, depending on whether the surgery is a one- or two-stage, a debride and implant retention procedure and whether the organism and host are favourable or not [70–72].

Antibiotic delivery can be systemic or local and each can used for varying lengths of time. All surgeons use intravenous systemic antibiotics to cover the initial operation, but conversion to oral can at

5 days to 6 weeks depending on the host and organism variables. The duration of oral therapy again varies from 6 weeks to 6 months. Local antibiotics can be delivered by a variety of media. Bone cement can be pre-mixed or hand mixed intra-operatively. In the uncemented revision knee replacement, antibiotic cement is often used in zone 1 to provide hybrid fixation and eradicate any dead space between implant and bone. Biodegradable implants such as Calcium Sulphate or Collagen fleece have been used to increase the intra-capsular antibiotic levels. Local antibiotics have the advantage of providing bespoke antibiotic usage at high concentration. Antibiotic impregnated bone graft has been reported successfully in the one-stage management of infected revision total hip replacements [55–57] and revision total knee arthroplasty [73] albeit in two stages.

Published Outcomes on Uncemented Revision TKA for PJI

Once a thorough debridement has been achieved, the remaining issues for the operating surgeon are: one- vs. two-stage, reconstruction of bone loss and long-term fixation. Regrettably there are so many variables that no randomised trials are possible to compare all the options. Common sense and experience tells us, however, that excellent outcomes can be achieved by a variety of means. Hence, provided the surgeon adheres to the good principles of infection clearance, antibiotic usage and delivery, and zonal reconstruction and fixation, an argument can be made for all philosophies. Other chapters will use literature to support their position and similarly we can review the published experience of uncemented revision TKA for infection.

Edwards et al. [5] in a retrospective study, compared cemented and uncemented diaphyseal stems at the second stage of revision for infection. Uncemented diaphyseal-engaging stems had a lower rate of radiographic failure than did cemented stems. This study did not look specifically at infection free survival but stem survival at a minimum 2 year radiographic review. However, reinfection rates were similar despite the absence of antibiotic cement in the cementless constructs. Vince and Long [62], however, reported earlier aseptic loosening in three patients after a two-stage re-implantation, from a small series of 13 patients revised using press-fit medullary stem fixation.

Bourne et al. [74] reported a series of 135 patients revised using uncemented press-fit stems of which 34 (25 %) were revised for infection in two stages. Of the infected revisions two had recurrent infection accompanied by radiolucent lines indicative of loosening. Agarwal et al. [4], looking at uncemented metaphyseal sleeve reconstruction and fixation in a minimum 2 year review, confirmed no recurrent infections in the 31 one-stage infected revisions. Similarly, Hanssen et al. [35] reported bony ingrowth into porous tantalum metaphyseal cones in a small series which included seven second-stage revision TKA. Bone ingrowth was unaffected by previous infection.

Using a two-stage protocol and "antibiotic-soaked" bone graft, Whiteside [59] used uncemented stem and screw fixation. Twenty-nine of 33 revisions were free of infection at mid-term review. Uncemented fixation has also been reported in limb salvage [61]. Using a two-stage protocol, cementless intramedullary nailing, without achieving bone-to-bone fusion, was used for treating chronically infected total knee arthroplasty. At 2 year review 89.5 % showed no recurrence of infection. No aseptic loosening or implant failure was reported.

Conclusion

Debridement is as much a formal part of any revision as is the reconstruction and soft tissue balance. By having defined stages which include surgical, mechanical and chemical debridement, a thorough and reproducible debridement is possible. The concept of repeated cyclical debridement is also vital to understand, as no surgeon can achieve adequate clearance of infection in a single pass. Finally, debridement should be seen as separate from reconstruction, which should not be prejudiced by inadequate debridement.

The concept of zonal reconstruction and fixation allows the surgeon to use their implants of choice in a methodical manner which should give reproducible outcomes. The published literature, although not extensive, confirms that uncemented fixation is at least as effective as cemented fixation in revision TKA for peri-prosthetic infection.

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