12 Cement-Bone Interface in Revision Arthroplasty

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Revision Total Hip Arthroplasty

For primary total hip arthroplasty (THA), several fixation options are available. Cemented, cementless, or hybrid principles have been applied, and their advantages, disadvantages, and their long-term effectiveness have been well described in the literature. A recent study reported the superior survival of cemented to uncemented THA which was related to better performance of the cemented cups [1]. On the other hand, uncemented stems have proved to perform better than cemented stems; the risk of revision was found to be similar in both implants [1].

As the early THAs were performed on relatively low-demand patients with end-stage osteoarthritis, as an alternative to Girdlestone's procedure, the occurrence of clinically symptomatic mechanical failure was low during the first 10–15 years of the application of arthroplasty surgery in clinical practice. Thus, experience with revision procedures was limited, and the clinical results were not easy to evaluate. Initially, cemented fixation was considered preferable for revision surgery, but the results were not satisfactory, with a high incidence of radiographic loosening and re-revision rates of both components [2–9]. It has been shown that the problem related to cemented revision lies in the quality of the remaining bone, following the removal of the components. Bone is often sclerotic without trabecular structure for cement interdigitation (Fig. 12.1). Advances in surgical techniques and implant technology have improved the long-term survival of primary THAs. However, the number of revision procedures has also been growing, and this is probably due to the increased number of THAs performed on younger, high-demand patients and because of the variety of hip disorders. Diagnostic and treatment recommendations have evolved, and several therapeutic algorithms have been proposed by many authors [10–13]. However, there is no consensus about the optimal treatment, and there are still questions regarding the indications of different techniques.

Cemented Acetabular Revision

Bone erosion due to osteolysis and mechanical damage from the motion of a loose component often leaves cavitary, segmental, and combined defects in the acetabulum [14, 15]. These changes

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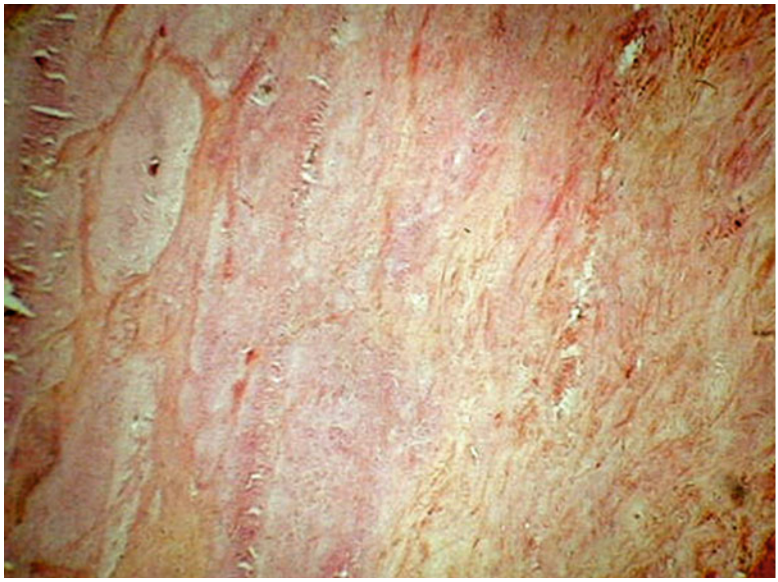

Fig. 12.1 Femoral endosteal surface after the removal of a loose femoral stem. Bone is sclerotic with absence of trabecular structure

in the bone stock can make it difficult to obtain adequate fixation of a cemented component in revision operations. At present, most authors agree that cementless fixation of the acetabulum in revision operations has better results than does cemented acetabular revision. Porous-coated acetabular components have demonstrated less radiographic loosening and lower re-revision rates [16–19]. Despite these, there is still a role for cement in the revision of acetabular cups. Cement is used for the fixation of a polyethylene component with a metal acetabular reinforcement ring or cage and particulate graft material; for fixation of a polyethylene component in conjunction with a large structural allograft, such as an acetabular allograft; and, in selected cases, for use with impaction grafting [20–27]. Another modern indication for the use of cemented polyethylene cups is the revision of a failed acetabular liner within the existing, well-fixed, metal shell. The technical parameters of this technique have been studied using an ovine animal model [28].

Type I acetabular defects can be managed with conventional either cemented or cementless cups and show satisfactory, at least midterm, results [29, 30]. For more severe acetabular defects, cemented fixation in revision THA shows unfavorable results. Acetabular migration and radiological and clinical loosening vary from 15 to 30 % in midterm [2–9, 31–33] with the best clinical outcomes reported by Marti et al. [34]. The use of reinforcement or anti-protrusio rings and cages in combination with cement fixation is a serious confounding factor in the assessment of clinical outcomes, and such an analysis is beyond the scope of this paper.

Cemented Femoral Revision

As in the acetabular side, type I femoral defects have intact cancellous and cortical bone. Any primary stem, cemented or uncemented, can be used performing third-generation cementing techniques, with a satisfactory clinical outcome [35].

Unsatisfactory clinical outcomes were also reported in early series of cemented femoral revision surgery. Fifteen to 30 % radiographic loosening and 5–9 % reoperation rate were observed in midterm at the hands of pioneers of hip reconstruction [2, 3, 5–7, 36]. The results were even worse if patients had had a previous revision, with reports of 50 % radiographic or clinical loosening at 3 years follow-up [6]. Another characteristic of this early revision surgery is the report of a high incidence of intraoperative or postoperative complications such as femoral canal perforations,

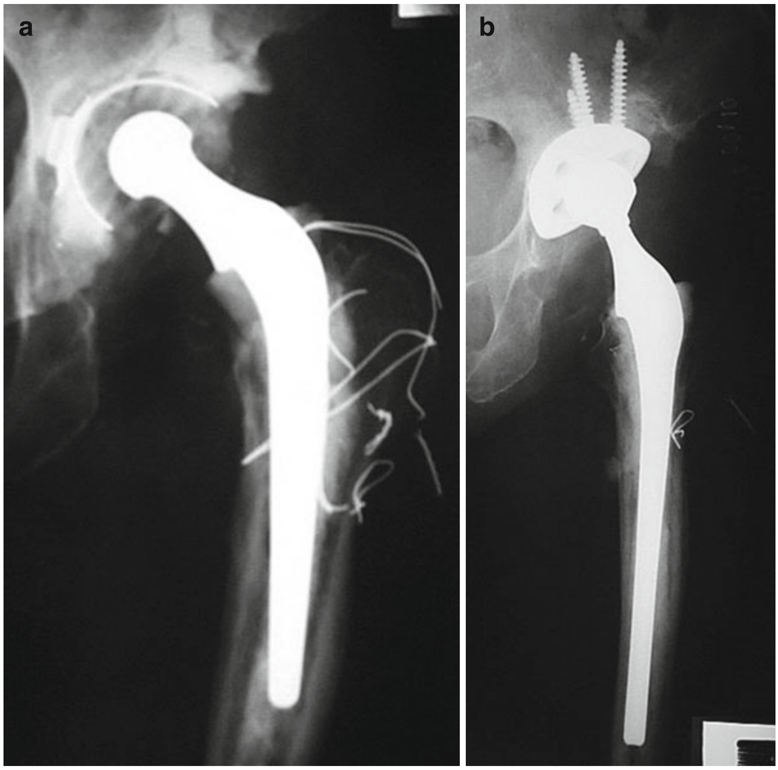

Fig. 12.2 (**a**) Preoperative radiograph of a THA with aseptic loosening. (**b**) Postoperative radiograph following a cemented femoral revision at 8-year follow-up

fractures, dislocations, femoral nerve palsy, and trochanteric problems. In this initial experience, the fibrous membrane between bone and loose cement and the neocortex between the fibrous membrane and any residual cancellous bone were not adequately removed. Cement delivery and pressurization systems were not available, and the distal canal was not adequately restricted (especially distal to the isthmus). Perforations of the canal were not recognized and appreciated and were bypassed. It was also not understood that perforations and canal windows can potentially act as stress risers. Modern cementing techniques, removal of the neocortex with a burr, recognition of the perforations (90 % of them to the anterolateral cortex), and bypassing the defects and windows by 1.5–3 diameters of the femoral shaft outer diameter have resulted in improved clinical outcomes. The re-revision rate of cemented revision of femoral stems dropped to 10 % at 10–15 years even in cases of extensive femoral osteolysis (Figs. 12.2 and 12.3) [32, 37–43].

Cemented Acetabular Revision with Impaction Grafting Technique

When notable bone loss and extensive bone defects exist, the impaction grafting technique with or without reconstruction rings and strut allografts should be used in cemented revision hip arthroplasty. It is important to recognize that primary implant stability in this technique depends on the adequacy of containment and impaction of the graft, together with effective cementing.

In the 1970s, clinicians began to use bone grafting to repair osseous defects in association with primary and revision hip arthroplasty. The size of the bone grafts used ranged from small morcellized to large bulk fragments [44–46]. Roffman et al. [47] have investigated the fate of autogenous chips under a layer of polymethyl methacrylate bone cement in an animal model with intrapelvic protrusio. Histologic evaluation revealed bone formation from the acetabular wall toward the graft. The graft appeared viable, and

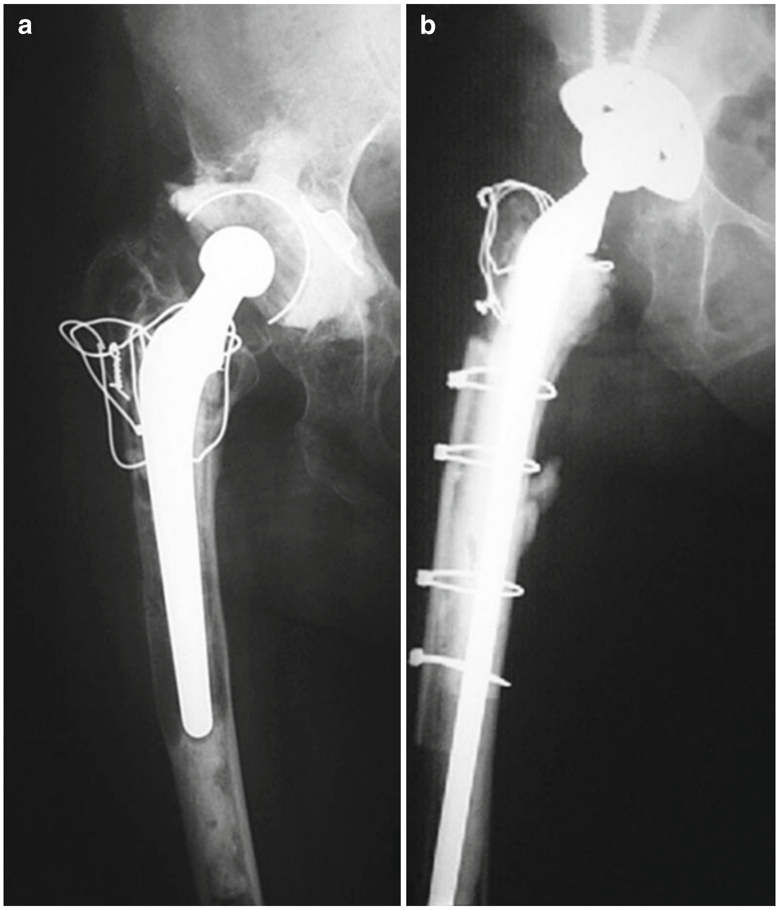

Fig. 12.3 (**a**) Preoperative radiograph of a THA with aseptic loosening and severe bone loss of the proximal femur. (**b**) Postoperative radiograph following a cemented femoral revision and strut bone allograft at 7-year follow-up

new bone formation was induced along the surface adjoining the bone cement. Other experiments in goats were designed to histologically evaluate the processes involved in graft incorporation. Surgical technique was comparable to that used in human procedures. Rapid union of the graft with host bone was achieved, and no signs of resorption or collapse of the reconstruction were seen [48–51]. Moreover, van der Donk has reported the results of human core biopsies taken from revision operations with impacted morcellized grafts and cement [52]. It was concluded that reconstruction of bony defects with impacted graft chips results in a new bony structure which can form an ideal substrate for cemented components. Griffon et al. [53] studied the biological behavior of biomaterials being considered for impaction grafting in revision hip arthroplasty. In their opinion, the biological properties of materials are very important and should be proved prior to evaluation under loading conditions.

On the acetabular side, the goals are to restore hip mechanics by placing the cup at the level of the anatomic acetabulum, to restore segmental defects with metal wire mesh in order to achieve containment, to restore periprosthetic bone loss by augmenting the cavitary defect with allograft bone chips, and to achieve stability by impacting the chips and using bone cement. On the femoral side, large bone chips (8–10 mm in diameter) must be used in the proximal femur to reduce subsidence of cemented stems especially when they are collarless, double tapered, and polished. Moreover, long stems are crucial in order to bypass regions of high stress concentration, while prophylactic cerclage wires and strut grafts are required when the femoral cortex is still thin and extends beyond the tip of the long-stemmed femoral component.

Recent studies have reported excellent mid-term and long-term survival of femoral component revisions with impaction bone grafting and a cemented stem [54–56]. Busch et al. have also shown satisfactory results using impacted morcellized bone grafts and a cemented cup in young patients with acetabular defects [57]. Buttaro et al. have suggested that metal mesh, impaction grafting, and a cemented cup should be considered for reconstruction of medium uncontained acetabular defects, but not for severe combined deficiencies. The reason for this is the migration of metal meshes, and the authors propose the use of acetabular reconstruction rings with impacted allografts in cases of extended segmental defects [25]. Results have been presented from the Swedish registry with its large population of patients and long-term follow-up. The survivorship of cemented stems used in combination with impaction grafting was 94 % at 15 years [58].

Cement-in-Cement Technique

If the cement is well fixed, a cement-in-cement technique appears to be a versatile and attractive alternative option (Fig. 12.4) [59]. Supporters of this technique report a low risk for bone loss, cortical perforation, and fracture as well as a lower probability of having to perform extensive osteotomies [12, 60, 61]. The concept of this technique was initially described by Greenwald et al. in 1978 [62]. The trend of removing all the old cement was questioned by their laboratory study which showed that recementing over previously hardened cement mass was feasible. They further propose rasping of the old cement surface in order to increase the area of contact and emphasize the early use of freshly polymerizing cement to allow larger amounts of monomer to interact with the old mantle. This was also supported by Weinrauch's biomechanical study in which the shear strength of 5 mm thick specimens was tested. The authors were able to analyze the possible reaction between the old and new cement mantle and attribute the quality of the chemical bond to the diffusion of new cement monomer [63]. On the other hand, Li et al. [64] reported in a biomechanical study that the strength of the bond between old and new cement can be dramatically reduced in the presence of blood and marrow debris. They propose the removal of the entire cement mantle if the previous one is not able to be thoroughly cleaned. However, in a recent biomechanical study where flexural strength was tested, it was shown that the interface between old and new cement was not a point of weakness [65]. In addition, different cement combinations did not significantly affect the strength of the interface. Other factors like the elimination of pores both at the interface and within the new cement appeared to be more important for the successful application of this technique.

Fig. 12.4 Postoperative radiograph of a cement-in-cement revision of a femoral stem at 5-year follow-up

Surgical Technique of Cement-in-Cement Revision Surgery

The surgical approach is usually the same as in primary THA. The cement above the shoulder of the hip prosthesis must be cleared to facilitate stem removal. Thus, inspection of the cement mantle is easier, and the cement can be removed to a depth where osseointegration of the old cement bone can be confirmed. If any crack in the old cement mantle is visible beyond the lesser trochanter level, it is better to remove all of the cement and perform an alternative procedure. Pulsed lavage is meticulously applied to clear the old mantle and different rasps, and curettes and burrs are used to roughen the cement surface. The new cement is prepared and introduced using a gun device while still in a low state of viscosity. Suction and compression techniques are used to avoid leaving any blood and marrow debris and to promote pressurization [10].

Regarding the acetabular component, this can be easily removed when it is loose without using extraction devices and osteotomes. If a polyethylene linear exists and loosening is minimal, then the technique proposed by Brogan can be performed [66]. During this procedure, larger reamers are used to ream away the implant under regular lavage and suction to minimize the escape of debris. After reaming, the polyethylene can be extracted much more easily, and the cement mantle is inspected to confirm its adequate fixation. The ridges of cement corresponding to the grooves in the polyethylene are retained, and additional small pits can be made to augment the contact surface. Penetration to the underlying bone should be avoided because the presence of blood debris will interfere with the new bond. The new component is inserted as usual.

Indications for Cement-in-Cement Revision Surgery

The cement-in-cement technique can be undertaken in different situations of revision such as the replacement of a broken component, the replacement of a malpositioned implant, and the conversion of a well-fixed hemiarthroplasty to THA [38, 67]. In addition, several authors support the use of the cement-in-cement revision in anatomically reducible periprosthetic fractures with a well-preserved preexisting cement mantle. After meticulous preoperative planning, this technique can offer decreased blood loss, decreased risk of iatrogenic fragmentation of bone during cement removal, and a safe alternative especially in elderly patients who are not fit for prolonged surgical procedures [13, 68]. Clinical studies using cement-in-cement technique in revision hip replacement have reported satisfactory outcome and long-term longevity of the implants. The majority of authors emphasize the advantages of bone stock preservation, the avoidance of extensive operating procedures, and the lesser risk of complications [12, 66, 69, 70].

Cemented Fixation of Revision Total Knee Arthroplasty

Due to the demographic development of western countries, the recent availability of technically advanced implants, and the expansion of indications for total knee arthroplasty (TKA), a further increase in primary TKA and, as a result, a corresponding rise in revision TKA are expected [71]. The most common causes of revision TKA are infection and implant loosening; the most common type of revision TKA procedure is revision of all the components [71, 72]. The literature related to clinical outcomes of revision TKA is limited, and studies are of low evidence (level III and IV), with a rather small number of patients, different implant revision systems, and short- to midterm follow-up [71]. Clinical survival rates from 71 to 94 % have been reported at the level of 10-year follow-up. Factors such as the component design, the restoration of the lower limb axis, the restoration of bone defects and knee stability, the underlying disease, and the implant bone fixation technique all influence the outcome [71, 73, 74]. Intramedullary stems improve the anchoring of implants especially in revisions with bone defects [71, 73, 75–78]; however, the fixation technique (cemented or cementless) for components and stems remains controversial [71, 77, 79, 80].

The biomechanical principles of cemented and cementless fixation in revision TKA have been studied in several experimental cadaveric studies [81–85]. It has been confirmed that tibial components with cemented stems show less micromotion than components with cementless stems of the same length. Tibial components with cementless long (150 cm) stems show similar stability as those with short (75 cm) cemented stems [81]. Tibial hybrid fixation shows less failure of fixation under cyclic loading compared to tibial cemented fixation [82]. The longer hybrid tibial stems show more equal and uniform load (shear) transfer compared to those shorter cemented tibial stems [83]. Primary stability of hybrid tibial stems is equal and even higher (depending on the tibial tray cement-bone penetration factor) compared to those of cemented tibial stems [84]. Hybrid femoral stems provide stability and minimize stress shielding of the distal femoral bone interfaces [85].

Mid- to long-term survival rates of hybrid fixation (a combination of cemented femoral and tibial components with cementless, press-fit femoral and tibial stems) vary from 71 to 96 % with an aseptic loosening rate between 0 and 29 % (Fig. 12.5) [73, 75, 77, 78, 86–90]. Mid- to long-term survival rates of cemented fixation (a combination of cemented femoral and tibial components with cemented femoral and tibial stems) vary from 89 to 97.5 % with an aseptic loosening rate between 0 and 7 % [73, 74, 79, 86, 91].

Fig. 12.5 Postoperative radiograph of a hybrid revision TKA at 8-year follow-up

Conclusion

The revision of cemented hip arthroplasties remains a challenge even in the hands of the most experienced orthopedic surgeon. Several important factors should be considered, such as acetabular or femoral bone loss, bone deformation, compromised soft tissues, stem fracture, and osteolysis. Comprehensive and well-designed preoperative planning is of great significance in dealing with these parameters. Restoring the hip joint center, establishing bone continuity, providing an implant that is well fixed to the host bone, and using bone graft, a surgical hip reconstruction can be achieved with favorable biological and mechanical characteristics and a successful long-term outcome. Cemented revision THA is indicated in older, low-demand patients with mild bone loss or large femoral canals, when using a proximal tumor arthroplasty for proximal bone loss in elderly patients and in revisions of infected arthroplasties. Impaction bone grafting and cement-in-cement techniques offer valuable alternative options in cases with compromised bone stock.

The ideal fixation of modular revision TKA remains unclear. Cemented and hybrid fixation show equal initial stability based on cadaveric studies, as well as comparable survival rates, comparable aseptic loosening rates, and equivalent clinical outcome based on mid- to long-term low-quality clinical studies.

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