Structural allograft and cemented long-stem prosthesis for complex revision hip arthroplasty: use of a trochanteric claw plate improves final hip function

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Received: 2 August 2006 / Revised: 7 September 2006 / Accepted: 7 September 2006 / Published online: 14 February 2007
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Abstract Extensive bone loss raises formidable challenges in total hip revision. The aim of this study was to evaluate the results of reconstruction using a cemented long-stem and massive structural allograft implanted in a filleted proximal femur, with and without the use of a trochanteric claw plate. Between 1988 and 2001, 44 revisions were performed in 42 patients. After a transtrochanteric approach, the femur was cut longitudinally. A long, cemented Charnley-type prosthesis was used, and flaps of the residual femur were folded around the allograft. The greater trochanter was reinserted with wires in all revisions, and with both wires and a claw plate in 20 revisions. Mean follow-up was 7.15 years (range: 3–16); seven patients, died and four were lost to follow-up. The follow-up exceeded five years in 34 patients. The major complication was nonunion of the greater trochanter, which occurred in 25 cases. Six dislocations, one recurrence of infection, two mechanical loosening, and two fractures below the stem were also recorded. The use of a trochanteric claw plate significantly improved final hip stability, even in patients with nonunion. Femoral reconstruction with a massive structural allograft is reliable and long-lived, and serious complications and long-term resorption are uncommon. The use of a trochanteric claw plate significantly improves final hip stability.

Level of evidence: Therapeutic study, level III (retrospective comparative study).

Résumé Les pertes osseuses, extensives sont un problème complexe dans les révisions de prothèses totales de hanche.

Le but de cette étude est d'évaluer le résultat de la reconstruction en utilisant une longue tige cimentée et des allogreffes massives implantées dans le fémur proximal avec ou sans ostéosynthèse du grand trochanter. Entre 1988 et 2001, 44 révisions ont été réalisées chez 42 patients. Après un abord transtrochantérien, le fémur a été ostéotomisé longitudinalement. Une longue prothèse de reprise de type Charnley a été utilisée et les fragments de fémur hôte ont été réamarrés autour de l'allogreffe. Le grand trochanter a été inséré avec des fils métalliques et dans 20 cas avec une plaque additionnelle. Le suivi moyen a été de 7.15 ans (de 3 à 16), 7 patients sont morts et 4 ont été perdus de vue. Le suivi a été supérieur à 5 ans chez 34 patients. La complication majeure est la pseudarthrose du grand trochanter qui est survenue dans 25 cas. Nous avons également observé 6 luxations, 1 récurrence d'infection, 2 descellements mécaniques et 2 fractures sous la queue. L'utilisation d'une plaque trochantérienne améliore de façon significative le problème de la pseudarthrose du grand trochanter. La reconstruction fémorale par des allogreffes massives est une technique fiable. Les complications à long terme avec résection de la greffe ne sont pas habituelles, l'utilisation d'une plaque trochantérienne améliore de façon significative le résultat final et la stabilité de la hanche.

Introduction

Extensive bone loss in the proximal femur remains a difficult challenge in patients who require hip revision surgery. Implant loosening and the attendant shedding of wear particles are closely associated with progressive bone loss, which may lead to extensive defects. Several options are available for managing extensive bone loss in the

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proximal femur. An uncemented massive stem fixed by press-fit or distal locking screws is widely used, with encouraging results [3]. When bone stock must be restored, impaction grafting seems to provide good results [7, 12]. Damage to the proximal femoral metaphysis may preclude the use of these techniques, however, leaving massive allograft reconstruction as the only solution. Studies have evaluated the short- or medium-term results of massive allograft reconstruction [9, 14] on the basis of technical differences, use of additional sterilisation [16], small sample size [18] and the pooling of patients requiring cancer surgery with patients undergoing joint replacement [15]. Several, more recent series [2, 8, 11] have reported results with comparable techniques and found a high rate of poor stability due to trochanteric nonunion. The objective of this study was to report outcomes in 44 consecutive cases (42 patients) of massive grafting for proximal femoral reconstruction and to evaluate the usefulness of a trochanteric claw plate for trochanteric fixation.

Materials and methods

We retrospectively reviewed 44 cases of proximal femoral reconstruction performed in 42 patients between February 1988 and March 2001. Two patients had repeated procedures.

There were 34 women and eight men, with a mean age of 60.2 years at the time of surgery (range: 25–79 years). The mean follow-up was 7.15 years (range: 2–15 years), and the follow-up was longer than five years in 34 patients. Four patients were lost to follow-up (after ten months in one case; two, five and 12 years postoperatively for the others). The patient with only ten months of follow-up was subsequently excluded from the study. Seven patients died before the chart review; they were included in the study and had a mean follow-up of 7.4 years. In all, 43 procedures in 41 patients were available for review.

The allografts were cadaver grafts harvested from multi-organ donors and obtained from the local tissue bank. All donors had undergone standard screening tests for transmissible diseases. All grafts were treated with gamma irradiation (25 K Grays), then stored at -70°C .

The mean number of surgical procedures per hip before allograft reconstruction was 3.8 (range: 1–9), and the mean number of total hip arthroplasties (THA) per hip was 2.5 (range: 1–5). The reason for revision was loosening of the existing prosthesis in all patients. Loosening was aseptic in all patients but one; the patient with septic loosening was treated with two-stage exchange and reconstruction.

The reason for the first arthroplasty was Crowe developmental hip dysplasia in 19 cases, primary hip osteoarthritis in ten cases (with a rapidly destructive course

in three cases), post-traumatic osteoarthritis in five cases, femoral neck fracture in three cases, rheumatoid arthritis in two cases, spondylarthropathy in one case, post-tuberculosis hip fusion in one case, secondary arthritis after hip infection in two cases and fibrous dysplasia of the femoral neck in one case.

Surgical procedure

Trochanteric osteotomy was performed routinely. The femur was cut transversely below the lower edge of the damaged area, and the residual metaphysis was split longitudinally to allow easy removal of the implant, foreign body granuloma and cement (Fig. 1). The graft was held in a vice and reamed with motorised reamers until it could accommodate the selected stem. Standard gentamicin-loaded cement was used to secure the stem to the allograft. The free part of the distal stem was then secured to the host femur using low-viscosity cement injected with a cement gun to maximise pressure. The two residual parts of the proximal host femur were placed around the allograft and held with cerclage wires. The greater trochanter was reattached with cerclage wires as described in Fig. 1. In 20 cases, trochanteric fixation included implantation of a trochanteric claw plate to minimise the risk of nonunion [4, 13] (Figs. 2, 3). This group is denoted Group A in the study. In 24 cases, reattachment was achieved with cerclage wires only; this second group is denoted Group B.

Evaluations

In keeping to the aims of this study, we reviewed the anteroposterior and lateral radiographs of the hip obtained immediately after the procedure and at the last follow-up. Preoperative bone loss was evaluated according to the D'Antonio classification (AOOS) [5]. Trochanter nonunion was defined as the visible migration of the trochanter. Union at the graft-host junction was considered to be complete when no residual radiolucent line was visible on the most recent anteroposterior views of the radiograph. Graft resorption was defined as resorption exceeding the original width of the allograft, according to Graham et al. [8] and corresponding to Gruen zones 1–7 [10]. We used the same criteria to assess the lateral radiographs for osteolysis.

Operating time was recorded, and total blood loss was calculated according to Rosencranch et al. [23]. Outcomes and adverse events were recorded as clinical or radiological. The patients were evaluated clinically before and after surgery using the Merle d'Aubigné and Postel grading system [19]. Prosthesis survival was assessed using the Kaplan-Meier method, the endpoint being revision for any reason. Aseptic loosening was assessed using the criteria described by Harris et al. [14].

Fig. 1 Description of the surgical technique

Statistical methods

The chi-square test was used to compare the occurrence of trochanteric nonunion. Mean stability values in the groups with and without trochanteric plate fixation were compared using a *t*-test. STATGRAPHICS (Sigma-plus SA, Levallois-Perret, France) software was used to create time survival curves calculated using the Kaplan-Meier method.

Results

Preoperative assessment

Preoperatively, the Merle d'Aubigné functional score was 10.02 (pain: 2.4; mobility: 4.8; function: 2.68). Hip preoper-

Fig. 2 Trochanteric claw plate to strengthen the fixation of the greater trochanter

Fig. 3 Radiograph showing claw-plate fixation of the trochanteric osteotomy

ative function was 2.70 in Group A patients and 2.67 in Group B patients. Radiographs consistently showed prosthetic loosening with extensive bone loss. According to the d'Antonio classification, 32 cases consisted of levels I, II and III lesions, 11 cases, levels I and II lesions and one case, level I lesions. The lesions were cavitory (Type II) in eight cases and combined (cavitory and segmental, Type III) in 32 cases; femoral discontinuity (Type VI) was present in two cases and isolated severe malalignment (Type IV) in two cases. Of the 24 Type III cases, two were combined with malalignment and one with Type II femoral lesions and a fracture. Femoral lesions were comparable in the two groups.

The allograft was a proximal femur in 38 cases, a distal tibia in four cases and a distal femur in two cases. Mean allograft length was 127 mm (range: 50–240 mm) (Group A: 125.5 mm; Group B 130 mm); in 28 cases, the length was greater than 100 mm. Mean stem length was 253 mm (range: 180–380 mm) (Group A: 247 mm; Group B: 256 mm). Mean operating time was 5 h 38 min (range: 3 h 10 min to 11 h) (Group A: 330 min; Group B: 332 min). Total blood loss (including pre- and postoperative bleeding) was usually about 100% of the blood mass (mean: 5108 ml; range: 1821–9569 ml).

The allograft was completely surrounded by the host bone on postoperative radiographs in 13 cases; in the 30 other cases, part of the allograft was directly exposed to the soft tissues. According to the Gruen and Amstutz zones, the calcar was exposed in seven cases and the lateral cortical bone in nine cases (zone 2 in five cases, zones 2 + 3 in three cases, zones 2 + 3 + 4 in two cases and zones 1 + 2 + 3 + 4 in two cases). In one case, the proximal femur underwent resorption and the entire allograft ultimately had no contact with the host bone.

Adverse events

Two patients experienced postoperative complications that consisted of fat embolism and stroke followed by partial recovery, respectively. Delayed complications consisted of nonunion of the greater trochanter in 25 cases and dislocation in six cases. Two patients each experienced a single episode of dislocation; this occurred during a stroke and a fall, respectively five and seven years after operation. The four patients with recurrent dislocation had an upward displacement of the greater trochanter. Of the 25 patients with trochanteric nonunion, 18 had this abnormality before the revision procedure was included in the study.

Union of the greater trochanter

Nonunion of the greater trochanter occurred in 11 of the 20 procedures with claw plate fixation and 14 of the 24 other procedures (nonsignificant difference: $P=0.6$). However, the

mean final stability score in the Merle d'Aubigné grading system was significantly better with claw plate fixation than without (5.0 ± 1.36 vs. 3.9 ± 1.33 , respectively; $P=0.043$).

Fate of the graft

Fusion between the allograft and host bone was obtained consistently (Fig. 4), with a mean time of 7.4 months (range: 4–12 months). In most cases, the graft showed no radiological changes during follow-up. Graft resorption occurred in five cases and consistently involved more than one-third of the thickness of the graft (Fig. 5). Graft resorption usually started at the site of a cortical defect through which grafted bone was in direct contact with the host soft tissues. Resorption always occurred before two years of follow-up and did not progress subsequently.

Outcomes at last examination

The mean functional score on the Merle D'Aubigné grading scale was 14.9. No clinical or radiological evidence of loosening was present for 39 stems. In the four remaining cases, complete stem loosening occurred; loosening was due to mechanical factors in three cases and to recurrent infection in one case. Of these four cases, three required repeat surgery. Recurrent dislocation required repeat surgery in three cases, all with major instability and nonunion of the greater trochanter; the treatment consisted of re-attachment of the greater trochanter and was successful in

Fig. 4 Fusion of the graft to the host bone 3 years after the procedure

Fig. 5 Graft resorption in the proximal area. Same patient as in Fig. 3, after 2 years of follow-up

all three cases, with no further episodes of dislocation. No cases of loosening due to graft resorption during follow-up were recorded. The final prosthesis survival rate with no further surgery was 82.4% (± 0.06 SD) at 14 years of follow-up (Fig. 6).

Fig. 6 Survival rate calculated using the Kaplan-Meier method

Discussion

Femoral reconstruction remains a difficult challenge in patients with extensive femoral bone defects, most notably those with loss of the cortical shell.

Although our study consisted of a higher number of cases and a longer follow-up than the majority of series reported to date, our conclusions are necessarily limited by its retrospective and nonrandomised nature. The surgical procedure was identical in all patients, which reinforces the validity of our observations.

Halliday et al. [12] obtained excellent results with trabecular bone grafts impacted into the intramedullary cavity of the femur. However, this method may be unsatisfactory in patients with decreased mechanical resistance of the host cortical bone, which precludes adequate compression of the mixed trabecular allograft. External reinforcement by a cortical strut can be used for small cortical defects, but this technique requires the presence of residual periosteum and is, therefore, not feasible in patients with extensive femoral loss. [21].

In patients with segmental cortical defects involving a large portion of the proximal femur, a massive structural bone graft must be used. Encouraging short- and medium-term results have been reported by Graham et al. [8] and Blackley et al. [2] with the same technique as that applied in our study, as well as by Haddad et al. [11] with a variant involving resection of the residual host femur (Table 1). Gross et al. [9] reported a 10.1% revision rate after at least two years of follow-up, but they did not cement the distal stem into the host femur; of the 130 patients, only one experienced graft resorption.

There was evidence of notable graft resorption in five cases in our study. Importantly, resorption did not impair stem fixation, and in all five cases, resorption occurred at a site where the graft was in direct contact with the soft tissue. Similarly, a high rate of graft resorption occurred in the study by Haddad et al. [11], who resected the residual host femur prior to grafting. Major resorption did not occur in our study when the graft was enclosed in bleeding host bone. This observation is consistent with that of a previous study in which three requirements for successful bone allograft reconstruction were identified [24]: stable fixation, inclusion within vascularised host bone and moderate mechanical loads through the graft. Long stems procure excellent immediate stability but limited mechanical stress. When residual bone flaps can be closed around the graft, prolonged graft survival is the rule. In patients with extensive defects precluding enclosure of the graft within host bone, osteoclastic resorption occurs, starting in the proximal part of the graft where mechanical stresses are lower due to stress shielding. Resorption starts within two years after revision but often stops after three years, as pointed out by Haddad et al. [11].

Table 1 Comparison of findings from four recent case-series^a (including our study) of patients who underwent proximal femoral reconstruction using the same technique

Series	Blackley et al. 2001 [2]	Graham et al. 2004 [8]	Haddad et al. 2000 [11]	Our series	Total
Number of cases	45	24	40	43	144
Follow-up (years)	11	4.5	8.8	7.15	8.4
Previous THA	3.8	4	2.6	3.8	3.5
Mean age (years)	62.5	64	58	61	61.1
Lost to follow-up	1	2	1	4	8
Trochanteric nonunion	14	20	18	25	73
Resorption	13	2	11	5	31
Infection	5	1	2	1	9
Graft-to-host bone nonunion	3	1	5	0	9
Recurrent dislocation	2	0	4	4	10
Aseptic loosening	3	1	0	3	7
Acetabular loosening	4	1	5	0	10
Survival rate	78% (9 years)		85% (10 years)	82% (14 years)	
Mean graft length (cm)	15			12.7	
Graft preservation	−70°C	−70°C	−70°C	−70°C	−70°C
Graft irradiation	2.5 Mrad	Yes	No	2.5 MRad	
Graft fracture	0	0	1	0	1

^a Note the higher rate of resorption in the study by Haddad et al., who resected the residual femur before grafting

Resorption involves immunological mechanisms that can be minimised by graft irradiation [22]. However, toxic compounds released after gamma irradiation of bone marrow in trabecular bone may cause adverse effects [20]. Furthermore, irradiation decreases the strength of cortical and trabecular bone [17, 25]. Fragmentation of irradiated grafts has been reported after five years of follow-up in patients treated for cancer [1].

Trochanteric osteotomy is the least invasive approach for complex hip revision. Reinsertion of the greater trochanter usually provides contact only with the graft, which does not allow consolidation. Migration of the trochanter often results in severe hip function, with a risk of recurrent dislocation. Our findings on trochanteric union are in keeping with earlier results obtained using the same technique [2, 7, 11] (Table 1). In an attempt to diminish the rate of trochanteric migration, Blackley [2] used a modified technique involving longitudinal osteotomy of the trochanter. Although partly effective, this technique is associated with a higher rate of proximal femoral damage. Emerson [6] reported that a bolt-and-plate fixation device increased the trochanteric union rate in patients with less severe femoral damage than those in our study.

Our results on hip function appeared to be improved by the use a specific trochanteric plate in this study. The two groups were similar with respect to age (mean age: 59.9 vs. 61.0 years), preoperative bone destruction, preoperative score in PMA score (mean global result: 10.02 vs. 10.05) and mean hip function score in PMA grading scale (2.70

vs. 2.67), mean operating time (330 vs. 332 min) or allograft length (125.5 vs. 130 mm).

The use of a plate as described in a previous case-series [4, 13] did not substantially increase the union rate in our patients, but it did appear to notably increase final hip stability. The final hip function score improved from 3.87 with only cerclage wires to 5.0 with a plate synthesis of the greater trochanter. This may be ascribable to the development of a fibrous sheath encasing the trochanteric fragment that restored continuity of the hip abductors. Claw plate fixation is now systematically used at our centre for major allograft reconstruction of the proximal femur.

Conclusion

Our results from femoral reconstruction using massive bone allografts and a long-stemmed prosthesis are encouraging after a mean follow-up of 7.15 years. Nonunion of the greater trochanter was the main complication and occurred in most of the cases. Osteolysis and resorption occurred in five cases and consistently involved a bone allograft that was not included in vascularised host bone. Resorption always occurred before two years of follow-up and did not progress thereafter.

Although the rate of trochanteric nonunion is difficult to reduce, the unwanted effects of nonunion can be minimised by claw plate fixation, which significantly improves final hip function, even in cases of nonunion of the greater trochanter.

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