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Original Article

An Alternative Solution to Achieve Primary Stability in Cementless Revision Hip Arthroplasty for Femur Ectasia

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Background/Purpose: Revision total hip arthroplasty is technically demanding, especially when treating a large defective femur. The aim of this study was to evaluate the clinical results of cementless total hip arthroplasty revision in patients with advanced femoral bony defects.
Methods: By using the canaloplasty technique, which osteotomized the proximal femur to reduce the width of canal, 12 patients were enrolled and underwent revision operation. Patients were evaluated by radiographic examination and Harris hip score before and after the index procedures.
Results: The average length of follow-up was 38.7 months. All the osteotomies united at a mean of 5.3 months. Structural allografts were used on six patients to augment the thinned cortices. A total of 11 femoral components (91%) achieved and maintained stability at the last follow-up. One patient was complicated with early stem subsidence and another with deep infection. Both patients were treated successfully without late sequelae. The mean Harris hip score improved from 37.2 to 75.0 after the operation ($p < 0.05$).
Conclusion: The canaloplasty technique could be an alternative solution to help revision surgery in some younger patients with advanced femoral defects.

Key Words: canaloplasty, cementless, femur osteotomy, onlay structural allograft, revision hip arthroplasty

Owing to the poor bone quality and the difficulty in achieving primary stability, revision total hip arthroplasty (THA) is technically demanding and is often associated with complications. It is especially challenging when treating a defective femur, which has extensive metadiaphyseal damage, with thin cortices and a widened diaphysis. One intraoperative problem might be that primary stability of the stem cannot be achieved, even with the largest prosthesis available. The potential solutions for this situation are shifting to a cemented stem, impaction bone grafting, custom-made cementless stem with distal interlocking screws, and allograft–prosthesis composite arthroplasty.

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All these methods intend to press-fit or fill the canal without changing the contours of the remaining cortices. Alternatively, modification of the shape of the canal to adapt the prosthesis could be a potential solution. Although the canal reduction procedure through femoral osteotomy has been reported,[1,2] it has not been as popularized and widely discussed as the other methods mentioned above.

The aim of this study was to review the clinical results of our patients who received a proximal femur osteotomy to downsize the canal for the purpose of cementless revision THA.

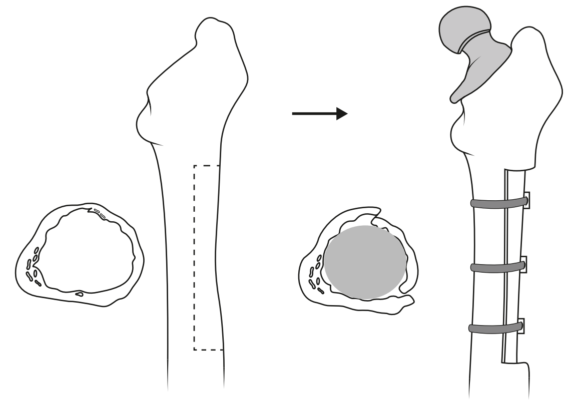

Figure 1. A bony shell is created by an osteotomy (dotted line) over the proximal to mid-shaft without disturbing the continuity of the femur. The shell is tightened up to the stem by the cable wires. The contact surface between the implant and the host bone is increased. Then the femoral stem is further impacted to the proper position.

Materials and Methods

From January 1999 to February 2003, 12 consecutive patients underwent modified proximal femur osteotomy during revision THA for the purpose of achieving secure press-fit fixation. Osteotomy was used when patients had a long segment of widened metadiaphysis of the femur and press-fit of the largest stem could not be achieved. Seven patients had Paprosky type III and five had type IV femurs.[3] Continuity between the greater trochanter and the diaphysis was intact in all these patients. The femoral stem used on these 12 patients was a long titanium stem with full hydroxyapatite coating on a rough surface (Restoration; Osteonics, Mahwah, NJ, USA).

The principle of the canaloplasty technique was to downsize the femoral canal by osteotomizing the femoral diaphysis. The surgical procedures were as follows. In the lateral decubitus position, the affected hip was explored through the standard anterolateral approach. The loosened femoral component was extracted with as little bone loss as possible. All the fibrotic tissues and the residual cement were removed. The medullary canal was reamed and prepared in the standard manner. When the largest stem failed to achieve primary stability during the provisional trial, canaloplasty was performed. At first, a cortical shell over the lateral aspect of the canal was osteotomized and mobilized carefully, with as much attached soft tissue as possible (Figure 1). The osteotomy started proximally at the lateral subtrochanteric area and reached the isthmus part of the femoral shaft. The length of the shell was 5–10 cm and the width was a third to half of the circumference. The greater trochanter was left intact to preserve the longitudinal integrity of the major bony structure. After completing the osteotomy, the shell was elevated and inspected again to avoid remnant cement or scar tissues. The femoral component was then inserted down the canal until its tip reached 2.5 cm above the expected final position. The shell was closed and tightened up to the femur, with multiple 2-mm cables. Subsequently, the component was hammered further down to the final position. Structural onlay allograft was used for two purposes: (1) to prevent the thin cortices being cut through by the cables; and (2) to embrace the proximal part of the stem to enhance the rotational stability. Finally, the proper size of the femur head was assembled and the stability of the arthroplasty was assured.

All the patients were regularly followed at 6 weeks, 3 months, 6 months and then annually after surgery. Weight bearing was not allowed for at least 3 months and then increased gradually according to the results of radiographic examination. Standardized anteroposterior and lateral radiography of the pelvis and femur was performed at each visit. The osteotomy site was interpreted as union in the following conditions: (1) callus bridging over the osteotomy; or (2) incorporation between the onlay allograft and the shell. Stability of the stem was judged from the clinical function, and the femur prosthesis was regarded as unstable radiographically if more than 5 mm of subsidence was noted. Harris hip scores[4] at the latest follow-up and before surgery were compared to evaluate improvement of function. Statistical analysis was performed with SPSS version 11.0 (SPSS, Chicago, IL, USA) with a paired *t* test. A significance level of 0.05 was used.

Results

There were 11 men and one woman (Table). Only one patient was diagnosed with primary osteoarthritis. The other patients were diagnosed with inflammatory arthropathy or avascular necrosis of the femoral head. Six patients underwent surgery as the first revision and the others had received revision more than once before. The mean interval between previous arthroplasty and canaloplasty was 16.6 years (range, 5–30 years). The mean age at the time of canaloplasty was 60.6 years (range, 51–80 years). These patients were regularly followed-up for a mean of 38 months (range, 12–72 months). During follow-up, one patient (case 2) died from unrelated medical disease 12 months after the revision operation. However, stable fixation of the prosthesis and union of the shell were recognized from radiological and clinical records since the fifth postoperative month.

Total operation time was an average 4.9 hours (range, 3.6–6.0 hours). The mean estimated intraoperative blood loss was 2.5 L (range, 1.3–3.8 L). Structural onlay allografts were used in six patients. The length of the shells was 10.5 cm on average (range, 8.5–13.0 cm).

There were no non-unions of the osteotomies. Union of the shells was recognized at a mean 5.3 months (range, 3.5–12 months) after surgery. Good stability was achieved in all the patients except one (case 7), whose stem was found to have subsided at the first month, but the patient refused

Table. Demographic and outcome data

Case	Age (yr)/sex	Arthropathy	Interval to latest arthroplasty (yr)	Use of allograft*	Time to union (mo)	Pre-op HHS	Post-op HHS	Complications	Follow-up (mo)
1	72/M	Osteoarthritis	9		3.5	35	77		72
2	53/F	Dysplasia	12	+	5	40	85		12
3	58/M	Avascular necrosis	9	+	12	33	81		45
4	54/M	Avascular necrosis	18		5.5	46	73		39
5	80/M	Avascular necrosis	24		3.5	15	60		38
6	51/M	Ankylosing spondylitis	34		6	28	68		42
7	63/M	Rheumatoid arthritis	14	+	4	35	66	Subsidence	33
8	58/M	Ankylosing spondylitis	22		2.75	48	75		30
9	54/M	Ankylosing spondylitis	5		5	41	76		30
10	76/M	Avascular necrosis	30	+	3.5	43	91		42
11	57/M	Avascular necrosis	5	+	6	39	65		36
12	52/M	Avascular necrosis	16	+	7	44	83	Deep infection	45
Average	60.6		16.6		5.3	37.3	75.0		38.7

**Structural onlay allograft. HHS = Harris hip score; Pre-op = preoperative; Post-op = postoperative; M = male; F = female.*

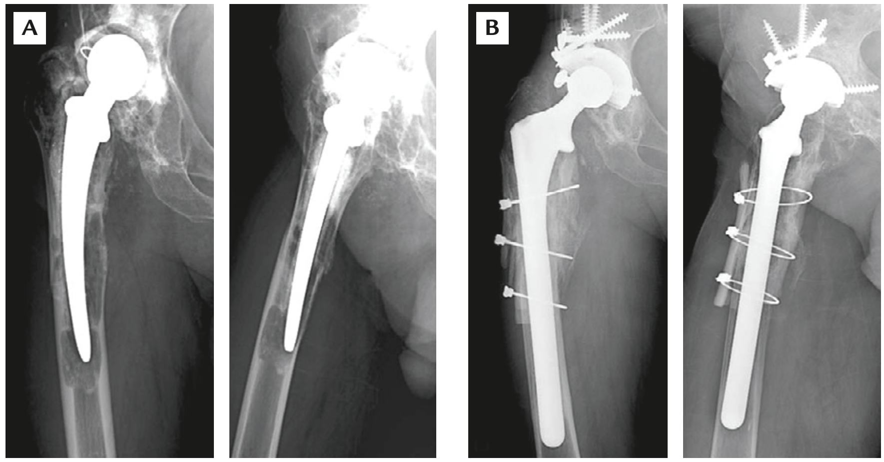

Figure 2. A 76-year-old man received all-cemented total hip arthroplasty 30 years ago. (A) Severe diaphyseal osteolysis with cement–bone loosening was demonstrated by preoperative radiography. (B) Radiography at 30 months after revision surgery with canaloplasty revealed solid union of the osteotomy and good incorporation between the graft and the host bone. The stem achieved good stability.

further surgery. Overall, 91% (11/12) of the stems remained stable and provided satisfactory functional results at the latest follow-up (Figure 2). There was no periprosthetic fracture in any of the patients. The mean Harris hip score was 37.2 (range, 15–48) before surgery and 75.0 (range, 60–91) after surgery. The functional status of patients was significantly improved after surgery ($p < 0.05$) and there was no difference in the function scores, regardless of whether onlay allografts were used. There was one case of delayed infection (case 12). The patient was treated successfully with early debridement and prolonged intravenous antibiotics.

Discussion

Even with meticulous preoperative templating, it was still not possible to achieve optimal press-fit during cementless revision with the largest and longest femoral stems. In such an unexpected circumstance, several potential solutions were considered, including shifting to cemented revision, impacted morselized allografting, custom-made cementless stem with distal interlocking screws, allograft–prosthesis composite, and proximal femoral replacement with mega-prosthesis.

Cemented femoral reconstruction is a feasible method to solve this urgent situation. However, under the circumstance that the femoral canal fails to press-fit a long prosthesis, the surface of the canal is usually sclerotic and lacks cancellous bone to provide good interdigitation with the cement. Another major consideration is the failure of the bone–cement interface and further compromise of the bone stock in the long term. A high failure rate of up to 26% has been reported previously.[5–11] In our study, most of the patients received first arthroplasty at a young age, and half had already received revision surgery. When considering the possibility of revisions in the future, preservation of bone stock cannot be over-emphasized. Therefore, we did not choose the option of cemented revision in these patients.

Cemented femoral revision with impacted morselized allografting was introduced in the early 1990s by Gie et al and was accepted as an alternative method due to its potential to reconstitute bone deficiencies.[12,13] However, this technique relies on solid compaction of the cancellous allograft by forceful and repetitive impacts, which might result in fractures over the weakened femoral shaft. Iatrogenic fracture rates > 10% have been reported.[14–17] Late postoperative fractures have also been reported, which might have resulted from an open section defect created during surgery and not corrected.[18,19] Subsidence of the stem is another concern. It has been proposed that creep deformation of the cement under constant loading or fracture of the cement mantle might play an important role in this scenario, and the rate of stem subsidence has been as high as 23% in some series.[20,21]

Cementless revision surgery provides more durable fixation than does cemented revision, once the osteointegration is well established. Almost all the fixation failures for cementless revision occurred in the first few years and were rare thereafter. In contrast, the failure rate for cemented revisions has increased with time.[8] The extensively coated stem has the benefit of pursuit of bony incorporation by providing a greater contact area between the host bone and implant, which therefore guarantees longevity.

Revision with a cementless distal locking stem has been postulated as another choice. Kim et al have reported a satisfactory result in 68 revisions using stems with distal interlocking screws over an average follow-up of 40 months.[22] Sotereanos et al also reported a 93% success rate in 17 revisions with this type of stem in a mean follow-up of 5.3 years. Theoretically, a distal locking screw can augment the stability of the whole construct. However, it cannot provide a press-fit over the coating area of the stem. Once the coating area fails to achieve primary stability, loosening with or without implant failure can eventually occur. There is no lack of reports to support this concern. Learmonth et al have reported fracture of the distal screw with stem subsidence in up to 22.7% of patients.[23] Additionally, femoral fracture associated with distal screw drilling or intraoperative stem impaction is also a concern because the remaining cortex over the diaphysis is weak and can be jeopardized during the procedure.[24] Furthermore, a distal locking stem is not always feasible immediately, and intraoperative stem processing is sometimes needed because this implant is custom-made.[24] Last but not least, the cost of this type of stem is high because a custom-made prosthesis can be expensive and unavailable in some regions.

Therefore, instead of seeking another type of prosthesis, osteotomizing and downsizing the canals seems to be a more feasible solution during surgery. Kim et al described the use of proximal osteotomy in cementless revisions for 36 patients.[2] The middle-term clinical results were satisfactory. However, their technique is different from ours. Although their technique creates a slot in the cortex by taking a wedge from the proximal femur, which might result in difficulties for symmetrical reduction of the canal, our technique creates a vital mobile bony shell to allow more even re-shaping of the canal to increase host bone contact. Furthermore, their technique is only applicable to the proximal femur, and for a diaphyseal defect it might result in unexpected cracks in the cortex.

There are several concerns when canaloplasty is performed. First, the greater trochanter is left intact to maintain the abductor mechanism. Second, the osteotomy should not extend over the distal third of the stem to avoid periprosthetic fracture, and the length of the mobile shell should be sufficiently long to achieve an effective canal. In our study, the length of the shell was 10.5 cm on average and the strength of the remaining constructs was not markedly compromised by the osteotomy. Third, onlay structural allografts should be utilized when a shell fracture is involved or bone stock augmentation is needed. Other allografts, either morselized or structural, could also be used at the enlarged proximal femur to enhance the rotational stability. Six patients in our study received an allograft, and five achieved stable host bone integration at the latest follow-up. The other patient was complicated with infection. Six patients without an allograft also obtained good results.

However, the canaloplasty procedure still has a prerequisite that the connection between the abduction mechanism and the femur diaphysis should remain intact. In a situation in which the proximal femur is totally absent, other options should be considered, including allograft–prosthesis composite[25] or proximal femoral replacement with a mega-prosthesis.[26]

In summary, failure to achieve primary stability of the stem in cementless revision THA could sometimes be salvaged by canaloplasty under certain circumstances. Although it is technically demanding and not without complications, our early results with the procedure are encouraging. A longer follow-up period and a larger number of patients are needed to further investigate this technique.

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