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Massive Revision Hip Arthroplasty: A Technique Utilizing Femoral Impaction Allografting and Collared, Textured Stems

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Abstract: Background. Revision of the femoral component in total hip arthroplasty in the presence of severe bone loss is a complex problem. Proximal femoral allograft stems have been utilized with some success but are limited by graft-host mismatch, lack of graft viability, and complexity of further revision. Impaction allografting with collarless, polished, tapered stems has been used successfully in cases of mild to moderate defects, but use in severe defects is limited by stem design and a high complication rate. The use of collared, textured stems with the impaction grafting technique may be a potential means of restoring femoral integrity and stability in these massive defects and may carry advantages to other methods of revision.

Methods. We present a retrospective case review of 18 hips in 17 patients having undergone revision total hip arthroplasty with impaction allografting and collared, textured stems. These revisions were selected from the entire case log of the primary surgeon because they met the selection criteria of having underwent a revision arthroplasty with impaction grafting, having Endo-Klinik grade 2 or worse femoral defects, requiring 150 cc or more cancellous allograft during femoral reconstruction, and having at least two years of follow-up. These hips were assessed with Harris hip scores and serial radiographs to measure clinical outcomes and radiographic signs of stem subsidence and failure. Bone scintigraphy and SPECT were performed on five hips during follow-up to examine graft activity

Results. Patients were followed for an average of 38 [24–56] months. Average Harris hip scores increased from 50 [17–73] preoperatively to 75 [40–100] at most recent follow-up. Seventeen hips were stable and functioning well at the time of most recent follow-up and exhibited no signs of stem subsidence or aseptic loosening on radiographs. There was one case of failure requiring further revision that was associated with visible subsidence and radiolucent lines on radiographs. SPECT analyses performed at an average of 37 [31–50] months postoperatively indicated active graft reorganization in all cases.

Conclusions. Impaction allografting with collared, textured stems may be successfully performed in cases of massive revision total hip arthroplasty and demonstrate good intermediate-term clinical results. The absence of stem subsidence on radiographs correlates with a successful outcome. This technique avoids the limitations encountered with proximal femoral allograft stems and collarless, polished, tapered stems and may be successfully utilized in the presence of severe femoral bone loss.

Introduction

Aseptic loosening is the predominant cause of failure in total hip arthroplasty and is associated with osteolysis. The resulting proximal femoral bone loss presents a challenge to revision arthroplasty, and restoration of structural integrity is vital to the success of any revision [1,24,36]. Severe defects define the most difficult revisions and prohibit the use of traditional cemented and cementless techniques [23,36]. Proximal femoral allograft long-stem prosthesis constructs have demonstrated success in multiply-revised patients with AAOS type II and III bone loss but in several reports have been associated with a high incidence of complications including dislocation, nonunion, graft resorption, and need for repeat operation [2–4,15–19,21,33,36]. The grafted bone serves as a structural allograft but remains inert and is not biologically incorporated into host bone [18,21]. Graft or implant size mismatch with the host may also be problematic [15]. The impaction allografting technique was initially described for treatment of primary protrusion acetabuli and in acetabular revisions but was later successfully utilized with the Exeter (Howmedica, Rutherford, NJ and Howmedica International, Middlesex, England) and CPT (Zimmer, Warsaw, Indiana) collarless, polished, tapered stems to revise Endo-Klinik grade 1 or 2 and AAOS type II and III femoral defects (Table 1) [4,7,8,13,14,32,38,42, 44]. While some studies have demonstrated success in more severe femoral defects, others have noted a high complication rate including massive early stem subsidence, cement mantle inadequacies, cement mantle fracture, femoral fracture, long-term subsidence, and catastrophic stem failure [9,25, 27,31,34,35,39,41,43,45]. Concerns over complications have led to a refinement in surgical technique and instrumentation, and studies using collared, textured stems have demonstrated good results with significantly lower stem subsidence rates [22,26,28,34,39].

While recent reports have been encouraging for the use of collared, textured stems in the impaction grafting technique, they have considered a general range of defects for which the method has been used [26,28]. In this study we will review a case series of "massive" revisions which traditionally would have been reserved for reconstruction with a proximal femoral allograft stem. We will review clinical and radiographic outcomes in the intermediate term and utilize SPECT analyses to examine graft activity with a minimum of two years follow-up. The demands of such massive femoral revisions include reconstitution of bone stock, im-

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Table 1. Description of femoral defects in the Endo-Klinik and AAOS classification scales [4,32]

	Defect	Description
Endo-Klinik	Grade 1	Prosthesis loose; radiolucent lines along proximal half of cement mantle
	Grade 2	Medullary cavity of proximal femur expanded by endosteal erosion; circumferential radiolucent lines
	Grade 3	Proximal femur expanded with widening of medullary cavity
	Grade 4	Gross destruction of proximal third of femur; use of long stem prosthesis precluded
AAOS	I (Segmental)	Loss of bone in outer cortical shell; may be specified as Level I (above lower end of lesser trochanter), Level II (within 10cm of lower edge of lesser trochanter), or Level III (greater than 10cm below lower end of lesser trochanter); may also be specified as partial or complete
	IIA (Cavitary)	Loss of cancellous/endosteal bone without extension to outer cortical shell
	IIB (Ectasia)	As IIA with expansion of femoral medullary cavity
	III (Combined)	Combined aspects of both segmental and cavitary defects
	IV (Malalignment)	Distortion of femoral architectural geometry; may be angular or rotational
	V (Femoral stenosis)	Partial/complete obstruction of femoral medullary canal
	VI (Femoral discontinuity)	Loss of femoral integrity secondary to fracture with possible nonunion

plant stability, functional restoration, and potential for future revision. If the impaction grafting technique meets these requirements, use of the method may be advantageous in these massive revisions.

Patients and Methods

The study set of cases was selected from a database of all revision total hip arthroplasties performed by the primary surgeon (J.P.G.). The primary surgeon in this study is well-experienced in the impaction grafting technique and has performed over 200 such procedures to date. The following criteria were defined for case selection: history of prior hip arthroplasty, Endo-Klinik grade 2 or worse femoral defects as determined from preoperative radiographs, a minimum of 150 cc cancellous allograft required in the impaction grafting process, and a minimum of two years follow-up. 18 hips in 17 patients met these criteria (Fig. 1). The patients selected were four men and 13 women with a mean age of 63 years (range 40–86) at the time of revision. In 12 hips revision was being performed for the first time, and in six hips prior revisions had been performed. Two hips had Endo-Klinik grade 2 defects, 13 had grade 3, and three had grade 4 [32]. Under AAOS classification one hip had a type IIB defect and 17 hips had type III defects [4]. The mean preoperative Harris hip score for all patients was 50 (range 17–73) [20].

In all patients we used cobalt-chrome alloy Spectron stems (Smith and Nephew, Memphis, Tennessee) with grit-blasted proximal and bead-blasted distal surfaces. A technique based on that described by Gie, et al. was performed in all cases [13,14]. Through a posterior-lateral approach, the existing stem was exposed, and the hip was dislocated through internal rotation. Attention was initially turned towards the acetabular component, and if judged necessary, revisions of this component were performed at this time. Attention was then focused upon the femoral component, which was removed either by hand or with an extractor mechanism. Residual cement was extracted using standard techniques. A synthetic plug was inserted into the femoral canal on a guide wire to serve as a base for cement insertion, and cancellous allograft was packed into the femoral canal. The guide wire was left attached to the plug at this time to guide appropriate subsequent insertion of cannulated tamps and reamers. In cases of cortical defects stainless steel mesh was fitted around the existing femur and extended to anatomically reconstruct the shape of the original femur. This mesh was supplied in two shapes, a 20cm by 10cm rectangle and a trapezoid with 5cm and 10cm bases and a 5cm height for use in proximal reconstruction. Six hips (#1, #3, #8, #12, #13, and #16, Table 2) required one piece of rectangular mesh, and three hips (#2, #5, and #10, Table 2) required approximately two pieces of rectangular mesh. One hip (#9, Table 2) required one piece of trapezoidal mesh, and two hips (#4 and #11, Table 2) required one piece of each type. Five hips (#6a, #6b, #7, #14, and #15, Table 2) required patches of mesh less than or equal to one half a full piece, and one hip (#17, Table 2) did not require mesh. The mesh was thoroughly packed with cancellous allograft following attachment to the femur and reinforcement with cerclage cables. Tamps were threaded over the guide wire and manually driven to pack distal allograft. Tapered, rotating reamers were then fit over the guide wire to peripherally pack the cancellous bone (Fig. 2). Following adequate impaction of allograft both distally and peripherally, the guide wire was removed from the canal leaving the plug distally fixed. Trial stems were fitted to the reconstructed femur, and an appropriate size was selected. Cement was inserted into the canal from the base of the canal to the surface using an extended nozzle, a Spectron stem was inserted, excess cement was removed, and the cement was allowed to cure (Fig. 3). An appropriate ball head was attached to the stem, and the hip was reduced. After the operative site was irrigated, the area was closed in layers. Postoperatively, patients were mobilized and made weight-bearing within two days. During this period patients were anticoagulated with aspirin.

For follow-up, patients were seen six weeks, three months, six months, and one year after their procedure. After the first year, follow-up visits were scheduled at one-year intervals. At each visit patients were assessed clinically with Harris hip scores, and radiographs of the operative hip were per-

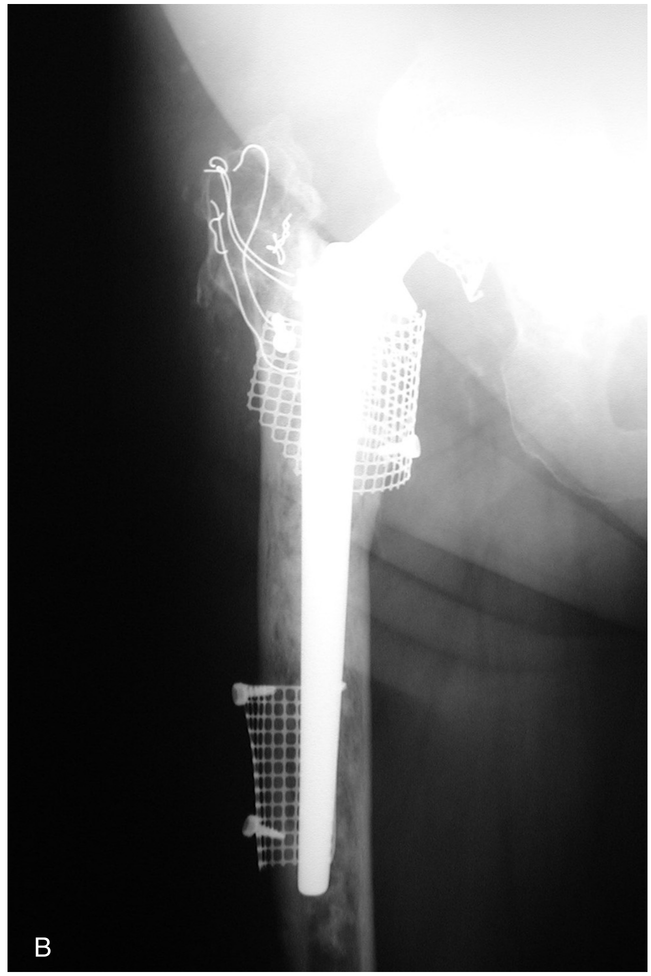


Fig. 1. Chronological radiographs of a patient (#7) having undergone massive femoral impaction grafting following severe bone loss. (**A**) Primary femoral stem in patient demonstrating Endo-Klinik grade 3 and AAOS III bone defects that include cement mantle fracture and significant loosening of the stem. (**B**) Radiograph of same patient 3 years following revision total hip arthroplasty utilizing impaction grafting. The revision stem is stable in the reconstructed femur and exhibits no signs of subsidence.

formed [20]. All patients were followed for an average of 38 months (range 24–56) at the time of the study. One patient died 24 months postoperatively from a cardiac event unrelated to his impaction grafting procedure. One patient had a

Table 2. Harris Hip Score statistics, preoperative radiographic classification, and clinical outcomes for patients having undergone revision total hip arthroplasty with massive impaction grafting

Patient	Endo-Klinik grade	AAOS grade	Bone Graft (cc)	Pre-op HHS	Most recent HHS	F/u time	Change in HHS	Outcome
1	4	III	150	17	55	51	38	Success; Contralateral stem loosening; peak HHS 99
2	4	III	360	59	93	50	34	Success
3	3	III	150	49	48	56	−1	Success; Contralateral stem revision; ipsilateral TKA; peak HHS 93
4	3	III	180	50	93	37	43	Success
5	3	III	300	68	82	35	14	Success
6a	3	III	180	71	44	49	−27	Failure from aseptic loosening; revised at 24mos
6b	2	III	240	73	80	44	7	Success; Contralateral stem revision; peak HHS 90
7	3	III	180	41	90	37	49	Success
8	3	III	360	38	84	31	46	Success
9	3	III	270	54	84	28	30	Success
10	4	III	270	70	90	31	20	Success
11	3	III	270	43	70	28	27	Success
12	3	III	180	36	67	24	31	Success
13	3	III	180	40	100	24	60	Success
14	2	III	180	53	57	24	4	Success; Deceased at 24mos
15	3	III	270	44	52	42	8	Success; Contralateral stem revision; peak HHS 97
16	3	III	180	36	78	40	42	Success
17	3	IIB	180	52	88	50	36	Success

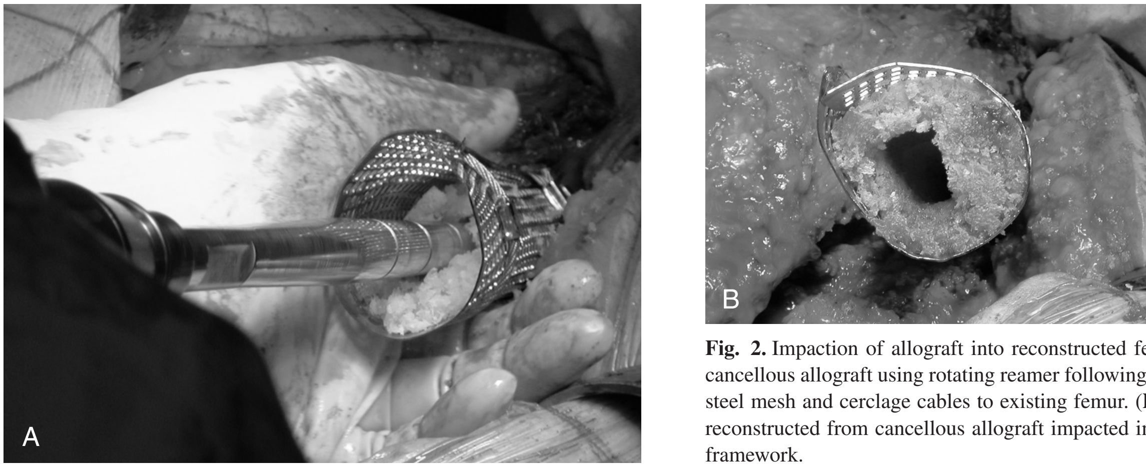


Fig. 2. Impaction of allograft into reconstructed femur. (**A**) Impaction of cancellous allograft using rotating reamer following attachment of stainless steel mesh and cerclage cables to existing femur. (**B**) Axial view of femur reconstructed from cancellous allograft impacted into stainless steel mesh framework.

failure of his revised arthroplasty 22 months after his operation and was re-revised with a new total hip arthroplasty and impaction grafting.

Five hips were selected from the original 18 to undergo triple-phase bone scintigraphy and single-photon emission computed tomography (SPECT) to assay the biochemical activity of the allograft in their operative hips during routine follow-up. These studies were performed 30 to 53 months after the patients' impacting grafting procedures. Scintigraphy studies were assessed visually by experienced nuclear medicine physicians.

Results

The average preoperative HHS for this series of patients was 50 (range 17–73). The patients had been followed postoperatively for an average of 38 months (range 24–56) during the time of the study. At the time of latest follow-up the average HHS for all patients was 75 (range 40–100) with an average improvement of 26 points (range 27–60) (Table 2). Eight of the 18 hips were associated with no or minimal pain for the pain component of the HHS. Two patients (#3 and #15) had undergone recent revision hip arthroplasties in the contralateral hip at the time of the study secondary to aseptic loosening of that femoral component. The HHS for the hips having undergone impaction grafting were 93 and 97 before the development of the contralateral problem. A third patient (#1) developed severe aseptic loosening of a contralateral hip prosthesis but declined revision hip arthroplasty. The HHS for this patient was 99 before the development of the contralateral pathology. At the time of the study all three of these patients were found to have stable femoral components on the side of the impaction grafting. One patient (#14) in this group died 24 months after the impaction grafting procedure from a myocardial infarction unrelated to his impaction grafting surgery. His hip prosthesis was functioning well at the time of his death. One hip (#6a) in the series developed aseptic loosening of the femoral component 22 months postoperatively that was diagnosed through serial radiographs and bone scintigraphy. The total hip arthroplasty was revised, and impaction grafting was repeated to improve femoral integrity. Four months after this revision the patient fell and sustained an ipsilateral femur fracture that required an open reduction and was fixed internally. This patient was the only patient among the 14-patient subset without recent contralateral prosthetic loosening who

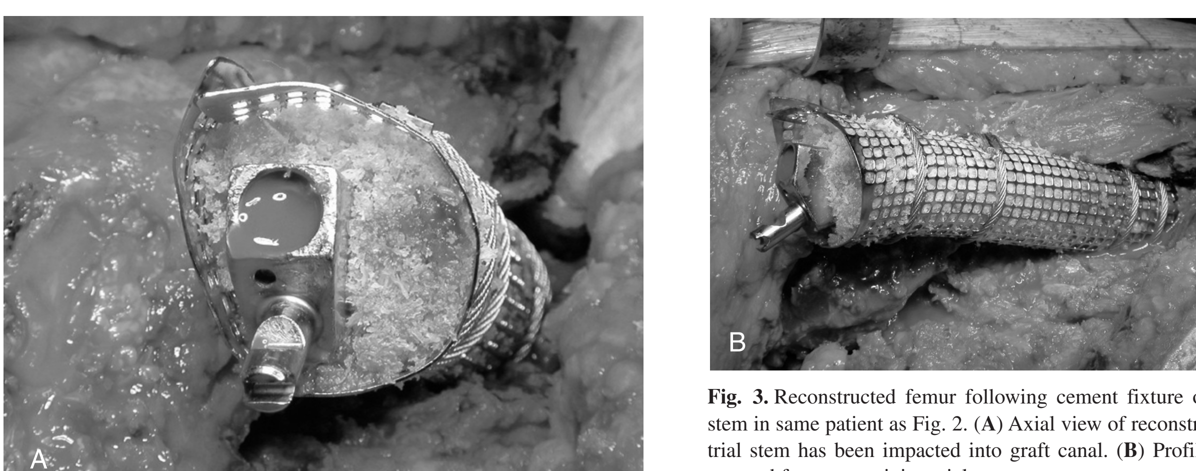


Fig. 3. Reconstructed femur following cement fixture of new prosthetic stem in same patient as Fig. 2. (**A**) Axial view of reconstructed femur after trial stem has been impacted into graft canal. (**B**) Profile view of reconstructed femur containing trial stem.

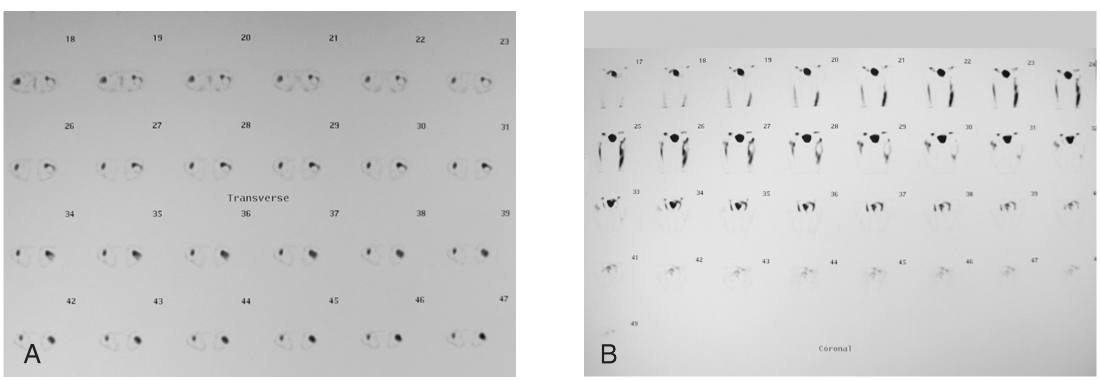
experienced an overall decrease in his HHS from preoperative to postoperative values (Table 2). The same patient had a successful contralateral revision arthroplasty using impaction grafting (#6b). The HHS for this contralateral hip (#6b) was 90 before aseptic loosening developed in his initially revised hip (#6a).

Radiographs were taken at each follow-up visit and examined for signs of subsidence and aseptic loosening. Radiolucent zones or lines were only found in the patient whose outcome was classified as a failure. In this patient radiolucent lines encircled the entire cement mantle in all Gruen zones and were adjacent to the stem in zones 3 and 4. Radiolucent lines were not evident in radiographs of any of the other 17 hips with a successful outcome. Subsidence measurements were based on comparisons of serial radiographs using the anatomic level of the stem collar and the stem tip as markers. Measurable subsidence of the stem within the cement was only seen in the patient listed as a failure. In this patient a stem subsidence of 5mm was demonstrated on radiographs taken 18 months after the first impaction grafting operation. Radiographs taken 14 months earlier had shown a femoral stem with no subsidence but radiolucent lines adjacent to the cement mantle in Gruen zones 2 through 7. No other hips exhibited signs of stem subsidence.

Bone scintigraphy and single-photon emission computed tomography were performed on five of the patients with successful outcomes (#2, #4, #5, #8, and #10). These patients had an average of 37 months of follow-up (range 31–50) and an average postoperative HHS of 88 (range 82–93). Scintigraphic examination demonstrated a significant amount of biochemical activity in the region of the allograft on the operative side. Activity involved both the periprosthetic region and the area of bone inferior to the prosthesis. This activity was significantly greater than activity in the contralateral femur (Fig. 4). An experienced nuclear medicine physician examined all three studies and reported the findings to be consistent with active revascularization, repair associated with ongoing incorporation of the allograft, and reorganization of the bony matrix.

Discussion

We performed a retrospective case series review to examine the outcomes of patients having undergone massive revision total hip arthroplasty with impaction grafting. The 18 hips selected for this study were chosen from the entire case log of impaction grafting revisions performed by the primary surgeon because they met the criteria of having undergone a revision total hip arthroplasty, having Endo-Klinik grade 2 or worse femoral defects, requiring at least 150 cc cancellous allograft for impaction grafting, and having at least two years of follow-up. Assessment was performed with Harris hip scores and serial radiographs in all patients and with SPECT in five patients.



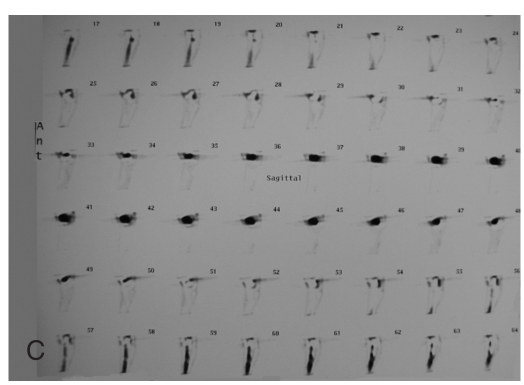


Fig. 4. Transverse (**A**), coronal (**B**), and sagittal (**C**) views of SPECT performed on a patient (#8) 30 months after a revision L hip arthroplasty with impaction grafting. Signal intensity is significantly greater in the left thigh compared to the right and is consistent with bone remodeling and revascularization.

Table 3. Comparison of studies using impaction grafting technique for revision hip arthroplasty. Exeter, CPT, Bi-Metric, and Head-Neck stems are all collarless, polished, tapered stems. Harris Precoat, Spectron, and Elite Plus stems are all collared, textured/unpolished stems.

Study	Stem	Hips	Endo-Klinik grade	Mean follow-up (mos)	Mean HHS	Number (%) HHS >80	Number (%) >1 mm Subsidence	Number Repeat Revisions
Gie et al.[14]	Exeter	56	1: 3 2: 40 3: 13 4: 0	30	N/A	N/A	11 (20)	2 (4)
Elting et al.[7]	CPT	56	1: 19 2: 22 3: 11 4: 3	31	90	50 (89)	27 (48)	3 (5)
Sloof et al.43	Exeter	10	1: 1 2: 4 3: 3 4: 2	24	94	9 (90)	N/A	N/A
Knight et al.[27]	CPT	30	1: N/A 2: N/A 3: N/A 4: N/A	31	86	N/A	15 (50)	2 (7)
Van Biezen et al.[45]	Exeter	21	1: 0 2: 0 3: 9 4: 12	60	78	10 (48)	17 (81)	0 (0)
Flugsrud et al.[9]	8 CPT 2 Exeter	10	1: 0 2: 1 3: 9 4: 0	48	80	N/A	N/A	N/A
Masterson et al.[34]	Exeter	35	1: 0 2: 6 3: 22 4: 7	N/A	N/A	N/A	7 (20)	1 (3)
Eldridge et al.[6]	CPT/ Exeter	79	1: 35 2: 25 3: 19 4: 0	13	N/A	N/A	18 (23)	N/A
Meding et al.[39]	CPT	34	1: N/A 2: N/A 3: N/A 4: N/A	30	87	28 (82)	15 (44)	3 (9)
Pekkarinen et al.[41]	Exeter/ Bi-Metric/ Head-Neck	68	1: 8 2: 22 3: 25 4: 13	36	N/A	N/A	42 (62)	13 (19)
Leopold et al.[28]	Harris Precoat	29	1: 2 2: 18 3: 8 4: 1	63	87	21 (84)	2 (10)	3 (12)
Karrholm et al.[26]	Spectron	24	1: 1 2: 16 3: 7 4: 0	32	76 (24 mos f/u)	N/A	N/A	N/A
De Roeck et al.[5]	Elite +	32	1: N/A 2: N/A 3: N/A 4: N/A	48	N/A	24 (77)	N/A	3 (9)
Present Study	Spectron	18	1: 0 2: 2 3: 13 4: 3	38	75	10 (56)	1 (6)	1 (6)

Spectron collared, textured stems were utilized in these cases because we believe that this stem is an excellent model for the type of revision system that functions well in the impaction grafting technique. The medullary canal expansion seen in Endo-Klinik grade 3 and 4 defects makes a reliable, stable revision very difficult to achieve and precludes the use of primary cemented and cementless stems [32]. Massive revisions demand a system with a range of stem, head, and neck lengths for successful proximal femoral reconstruction and minimal leg length discrepancy to be achieved. The Spectron system provides stem lengths from 135 mm to 215 mm, head sizes from −3 to +16, and several neck sizes to meet this need. This revision system has demonstrated excellent long-term survival and cement fixation [10–12]. We believe that when used with specialized instrumentation, including cannulated tamps and rotating reamers, this system is able to achieve optimal graft stability and stem fixation and maximizes the potential for long-term success in massive revision [26,28,45].

All hips that did not require a repeat revision achieved a significant improvement in their Harris hip score. In four hips (#1, #3, #6b, #15) a contralateral hip problem caused Harris hip scores to decrease from peak postoperative levels; however, three of these hips maintained an overall improvement from preoperative values. Only one hip (#6a) required a repeat revision, and this hip was associated with a decrease in Harris hip score from the preoperative value. Our clinical results are comparable to other studies using collared, textured stems (Table 3) [5,26,28]. Leopold, et al. described a Harris hip score of 80 and above as a good or excellent rating and noted that 91 percent of patients who achieved this score did not require a repeat revision [28]. Our results are similar, and no hips with a recent or peak score of 80 or greater required an additional revision. In addition, it should be noted that the rate of Endo-Klinik grade 3 and 4 femoral defects was significantly higher in our study than in others using collared stems [26,28]. When compared to some studies using collarless, polished, tapered stems, our clinical outcomes are somewhat worse, but these studies had a much lower proportion of severe defects [7,14,43]. Studies using collarless stems with a similar proportion of severe defects had clinical results very similar to ours [9,45].

No stem subsidence was seen on radiographs for any patient who did not require a repeat revision. The only patient to show signs of stem subsidence and radiolucent zones in the cement mantle required an additional revision. These findings may suggest that for this revision system the presence of subsidence and radiolucent lines in the cement mantle indicate a poor prognosis. While the large amount of mesh required in some revisions makes tracking stem subsidence difficult, this problem is overcome by using the stem collar as a reference point. The rate of stem subsidence in studies of collared stems is significantly less than that for collarless stems [6,7,14,27,34,39,41,45]. Opinions on the role of subsidence in collarless, polished, tapered stems have been inconsistent and have suggested both links to cement mantle stability and failure [6–8,14,31,34, 45]. For collared stems, failures in our study and in Leopold, et al. have occurred in the process of subsidence [28]. This correlation may provide a better prognostic indicator when collared stems are used.

Histological studies have suggested that allograft adjacent to the femoral cortex is reorganized, revascularized, and viable, but describe a more varied appearance in the deeper regions of the grafted bone. These regions of allograft consist of a mixture of fibrous, vascular, and osteoid tissue [29,30,40]. Our SPECT results are consistent with these findings and suggest active reorganization even up to 50 months after revision. Similar results have been found at earlier follow-up times [37]. This activity is important for both femoral stability and future operative considerations. These findings are in contrast to those for proximal femoral allograft stems, in which the allograft remains inert, and graft resorption may be a cause for concern [15–19,21,33].

In conclusion, we feel that impaction grafting with a collared, textured stem is a promising technique for the repair of severe femoral defects in revision total hip arthroplasty. We believe that our study is the first to examine collared stem use in a group of cases all characterized by massive revisions. Our clinical and radiographic results compare well with other studies of collared stems and with studies of collarless stem use in severe defects while allowing for the tracking of stem subsidence. We believe that the advantages of this technique in severe defects are the active reorganization of graft and the solution of graft-host mismatch when compared to allograft-stem composites. Our results are supportive for continued use of impaction grafting involving collared, textured stems in massive revision total hip arthroplasty and advocate future work to further examine use of the procedure in patients with severe loss of bone stock.

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