Original Article Clinics in Orthopedic Surgery 2023;15:734-739 • https://doi.org/10.4055/cios23052

Long-term Follow-up Results of Femoral Revision Hip Arthroplasty Using Impaction Bone Grafting and Standard Cemented Polished Stem

Jin Sung Park, MD, Seok Hyun Kweon, MD, Sung Ju Kang, MD, Yang Hun Jo, MD

Department of Orthopedic Surgery, Wonkwang University Hospital, Iksan, Korea

Background: To report the long-term clinical and radiologic results of impaction bone grafting and standard cemented polished stem for femoral revision arthroplasty in patients with extensive bone deficiency.

Methods: We retrospectively reviewed 47 hips that underwent femoral revision hip arthroplasty using an impaction-morselized allograft with a standard cemented polished stem. The average age at the time of revision hip arthroplasty was 55 years (range, 39–75 years). The modified Harris hip score (HHS) was used for clinical evaluation. The radiologic evaluation focused on stem subsidence, stem position, progressive radiolucent lines, bone remodeling, and the incorporation of allografts.

Results: The modified HHS improved from an average of 55.04 (range, 25–79.5) preoperatively to 90.1 (range, 81–93.2) at the last follow-up. The mean follow-up duration was 13.5 years (10.9–17.8 years). The radiographic analysis revealed stable stems. Femoral stems showed an average subsidence of 3.2 mm (range, 2–8 mm) in the cement mantle. However, there was no mechanical failure or subsidence of the cement mantle in the femurs. The stem position was neutral or varus less than 5°. No progressive radiolucent line or osteolysis was observed. Evidence of cortical and trabecular remodeling was observed in all cases. There were four cases of intraoperative cracks and four cases of distal femur splitting.

Conclusions: Initial stem stability using impaction bone grafting and a standard cemented polished stem in femoral revision arthroplasty resulted in good outcome. Delicate impaction grafting techniques and intraoperative crack and splitting fixation are the points that need attention for successful long-term results.

Keywords: *Cemented polished stem, Revision hip arthroplasty, Impaction bone-grafting*

Femoral bone defects due to aseptic loosening, mechanical instability of the prosthesis, infection, and iatrogenic bone loss are important issues in revision hip arthroplasty (RHA), and there are several differences in the methods used to achieve successful results. In the case of sufficient femoral bone (diameter ≤ 18 mm), methods using a cementless extensively porous-coated precoated femoral stem have been used.[1] However, the loss of femoral bone stock with ectatic metaphysis or diaphysis remains a major challenge in RHA. It is difficult to obtain initial stable fixation of the femoral revision stem and long-term survival. Impaction bone grafting (IBG) is an established reconstruction technique used to restore severe bone loss in RHA. While IBG is technically demanding and adverse events have been reported,[2-4] it is now recognized that there are distinct advantages of the technique, including both preservation of the bone and remodeling of IBG into living bone.[5-8] We report clinical and radiologic long-term results of using IBG and a standard-length cemented collarless, polished, tapered (CPT) stem for RHA in patients with extensive bone deficiency.

Received February 22, 2023; Revised May 2, 2023;
Accepted May 4, 2023

Correspondence to: Seok Hyun Kweon, MD
Department of Orthopedic Surgery, Wonkwang University School of Medicine, 895 Muwang-ro, Iksan 54538, Korea
Tel: +82-63-859-1360, Fax: +82-63-852-9329
E-mail: osksh@wku.ac.kr

METHODS

Study Subjects

The research protocol was approved by the Institutional Review Board of Wonkwang University Hospital (No. WKUH 2019-07-013), which waived the informed consent of patients. We included patients with extensive bone loss involving more than one third of the proximal femoral area, no initial stem stability with a cementless long stem bypassing the deficient area, and young patients needing biologic restoration for future re-revision. We retrospectively reviewed 47 hips (43 patients) that underwent RHA using IBG and standard cemented polished stems for extensive femoral bone defects in our hospital between July 1997 and February 2012. There were 37 men and 10 women with an average age of 55 years (range, 39–75 years) (Table 1). The mean time between primary hip replacement and revision surgery was 9 years (range, 1–12 years). In most cases, the diagnosis at the time of primary hip replacement was osteoarthritis and avascular necrosis. Overall, 39 cases of cemented femoral stems and 8 cases of cementless femoral stems were revised in this series. The mean follow-up duration was 13.5 years (range, 10.9–17.8 years). The causes of revision were aseptic loosening (n = 38), septic loosening (n = 5), and periprosthetic fractures (PPF) (4 cases). Femoral loosening with bone defect according to the Endo-Klinik classification[9] was grade II (12 cases), generalized radiolucent zones, endosteal erosion and widening of the medullary cavity; grade III (16 cases), expansion of the proximal part of the femur; and grade IV (11 cases), gross destruction of the upper two-thirds with involvement of the middle third. Sclerotic radiolucent lines > 1 mm around the femoral stem were defined as a dissociation occupying > 50% of the femoral zones.

Notably, 37 cases were Exeter (Howmedica, London, UK) and 10 cases were CPT (Zimmer, Warsaw, USA) used for revision of the femoral side. Acetabular cup revision was performed in 39 cases, acetabular roof reinforcement ring with hook (Ganz, Proteck, Baar, Switzerland) was used in 9 cases, cementless HG II (Zimmer) was used in 5 cases, CLS expansion (Sulzer Orthopaedic, Baar, Switzerland) was used in 7 cases, and Trilogy (Zimmer) was used in 18 cases. It was observed that 42 patients underwent one-stage reconstruction for aseptic loosening or PPF and all 5 patients with bacterial infection underwent two-stage reconstruction. The modified Hardinge approach (39 cases) in the lateral position was used as in the primary approach; however, when a wide field of view was required, the trochanteric slide approach (8 cases) was used. The mean usage of allogeneic femoral head was 3, wire mesh and Dall-Miles cable in 17 cases, only Dall–Miles cable in 8 cases, and strut allograft and Dall–Miles cable in 11 cases. Commercialized strut allografts and femoral head allografts (fresh frozen) from a patient who had un-

Table 1. Patient Data and Bone Defects

Variable	Bone defect				*p*-value
	Grade II (n = 12)	Grade III (n = 16)	Grade IV (n = 11)	Total	
Age (yr)	52.7 (43–64)	55.3 (39–75)	54.7 (44–66)	54.3 (39–75)	0.205*
Male : female	5 : 7	7 : 9	5 : 6	17 : 22	0.831†
Right : left	6 : 6	7 : 9	5 : 6	18 : 21	0.718†
Original diagnosis					-
Osteoarthritis	7	11	7	25	
Avascular necrosis	2	3	3	8	
Hip Fracture	2	2	1	5	
Other	1	0	0	1	
Number of revisions					0.373†
First	11	13	9	33	
Second	1	3	2	6	

Values are presented as mean (range) or number.
*Mann-Whitney *U*-test, unless otherwise stated. †Pearson chi-square test.

dergone hip arthroplasty for a femoral neck fracture or osteoarthritis were used. Femoral allobones were kept frozen at a minimum of –80 °C or below for use, and before freezing storage, aerobic and anaerobic tissue cultures of tissues collected from the bone, synovium, and joints were performed. The grafted bone was cut into 5–10 mm in size using a milling machine, rongeur, cutter, etc., and several irrigation procedures were performed. After removing as much water as possible, powdery cephalosporin (sometimes vancomycin) was added. The dissociated femoral stem and bone cement were removed. If infected, the joint capsule and fibrous tissue were thoroughly removed and cleaned with pulsatile irrigation. Subsequently, an acrylic plug was placed 2 cm distal to the osteolytic site to block the distal femur. In case of segmental defects in the cortex or calcar and a large ectatic metaphysis or diaphysis, a metal mesh or additional reconstruction with strut allografts for IBG was performed using Dall-Miles cables (Fig. 1).

From the distal part of the femoral bone, we placed a morselized allobone while using a packing device with strong pressure on the plug. After reaching the proximal femur around the trochanter area approximately 8–10 cm from the distal end, the slightly larger morselized allobone (> 5 mm) was firmly pressed against the inside of the femoral canal with assembled femoral tamps 2 mm larger than the final one, and the neo-medullary canals were reconstructed. After the trial stem reduction, morselized allobone filling and pressure were repeatedly applied until the proximal portion was filled. Strong pressure was applied to maintain stem stability. After satisfactory reduction,

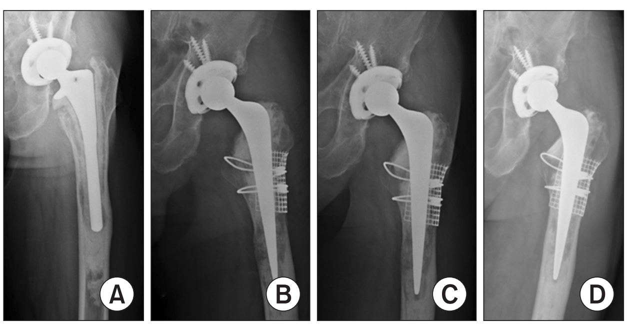

Fig. 1. (A) Preoperative radiograph of a 64-year-old man who showed aseptic loosening and osteolysis in all femoral zones and extending into the diaphysis. (B) Postoperative radiograph of femoral reconstruction using a mesh and an impacted cancellous allograft with a standard cemented stem. (C) Radiograph at 3 months postoperative showing trabeculation and cortical bone repair. (D) At 13 years, radiograph showing 2-mm subsidence, trabecular remodeling of the grafts, no loosening, no osteolysis.

the trial stem was removed and the new bone marrow was dried. Bone cement containing antibiotics (Simplex-P, Howmedica) was filled into the new bone cavity using the retrograde method with a cement gun. After the entrance was sealed, the bone cement was distributed into the grafts. Compression was maintained until the viscosity of the bone cement was adequate, and a standard polished femoral stem that was 2 mm smaller than the trial stem was inserted. Intraoperatively, preventing cement leakage around the periprosthetic femoral fracture like crack or splitting and severe bone defect was done by cerclage wiring with metal mesh and struct allograft to make a contained type. Postoperatively, bed rest was recommended for 1–2 weeks; after 3 weeks, wheelchair ambulation and weight-bearing were progressively increased with two crutches for 1–3 months with partial weight-bearing walking.

Research Methods

The clinical results were analyzed using the modified Harris hip score (HHS) by observing the preoperative and last follow-up results. Thigh pain was assessed at the last follow-up visit. Radiologically, anteroposterior and lateral radiographs at the time of surgery and at the last follow-up were compared and analyzed. The following radiologic reviews were recorded: subsidence of the stem, stem alignment, periprosthetic fracture or fracture of the stem, radiolucent lines by zones at the stem-cement, cement-bone interface, fracture of the cement mantle by zones, cortical repair and trabecular remodeling, and incorporation of allobone grafts. The subsidence was measured on the shoulder of the stem. The degree of subsidence was classified as less than 5 mm (minimal), 5–10 mm (moderate), or >10 mm (massive). The femoral component was divided into sections by Gruen et al.[10] The recovery of the cortical bone was defined when the thin and eroded cortex was restored to the same thickness as the normal cortical structure. Trabecular remodeling was a case in which the shape of the graft was changed by trabecular movement in the diagonal direction from the femoral endomembrane to the cement.[11] We observed other complications during and after surgery.

RESULTS

Clinical Results

The modified HHS improved from an average of 55.04 (range, 25–79.5) preoperatively to 90.1 (range, 81–93.2) at the last follow-up. Sixteen cases were excellent, 25 were good, and 6 cases were normal. Mild thigh pain was ob-

Table 2. Radiographic Results

Variable	Number of hips (%)
Subsidence (mm)	
< 5 (minimal)	22 (78.6)
5–10 (moderate)	5 (17.8)
> 10 (massive)	1 (3.5)
Graft incorporation	
Cortical bone repair	23 (48.9)
Trabecular remodeling	30 (63.8)
Unchanged graft appearance	0

served in 3 cases at the final follow-up. However, the pain did not limit daily activities.

Radiological Results

Stem-cement subsidence was 5 mm (minimal) in 22 cases, 5–10 mm (moderate) in 5 cases, and > 10 mm in 1 case (Table 2). Femoral stems showed an average subsidence of 3.2 mm (range, 2–8 mm) in the cement mantle. There was no subsidence between the cement and grafts. The stem alignment was neutral in 24 cases and varus in 4 cases. Varus stem alignment was within 7°, and no progressive or dissociated findings were observed. There were 23 cases of cortical bone repair and 30 cases of trabecular remodeling. No radiolucent lines > 2 mm or osteolytic zones were observed.

Complications

Complications were fixed using a Dall-Miles cable in 4 cases of proximal femoral linear cracks that occurred intraoperatively, and distal femoral splitting was fixed using strut allografts and a Dall-Miles cable in 4 cases. There were no postoperative complications, such as periprosthetic fracture, loosening, infection, inflammation, vascular or nerve injury, or dislocation.

DISCUSSION

Since the introduction of femoral impaction grafting for stem revision in the early 1990s, there have been numerous reports of clinical success in the literature.[12,13] However, there is concern regarding stem subsidence, intraoperative fracture, and PPF postoperatively.[14,15] On the biomechanical side, allogeneic impacted cancellous bone grafting was performed using wire mesh or structural allograft to make non-containment as a containment, compression bone graft was used to reconstruct the bone defect site, and initial stabilization of the stem-bone cement-compression bone graft structure was obtained by using bone cement to aggregate the bone cement and graft. Schreurs et al.[16,17] reported that firm fixation of the femoral stem was obtained through compression bone grafting and was reinforced by using bone cement. Gie et al.[11] reported bone graft incorporation in 54 patients at 30 months of follow-up and found satisfactory clinical and radiological results. Elting et al.[18] reported an average of 90 HHS in 56 patients. There was no pain in 80% of the patients at the 31-month follow-up, and there was no dissociation of the femoral stem. In our study, the mean modified HHS improved by 90.1 and 87.2% at the mean follow-up of 13.5 years, showing good results without any complaints of pain. In addition, bone graft incorporation was confirmed in radiological follow-up. There was no evidence of dissociation between the stem cement and the cement-grafted bone.

Biological and histological findings are characterized by revascularization of the impacted bone graft, resulting in the resorption of bone by bone-destroying cells and formation of woven bone in the grafted bone remnants. The host bone supplies blood and living osteoblasts, which is a critical factor in incorporation and regeneration of the dead bone graft. It has also been reported that new bone is formed in the fibrous aggregation site or without a scaffold of the fibrotic matrix, and most of the grafted bone is reformed into normal lamellar bone.[19] Ling et al.[20] reported that allografted bone was replaced with new bone tissue in biopsy after impacted allograft. Nelissen et al.[7] found that living bone marrow was present and new cortical bone was formed in the bone histology obtained from a large area of the hip during revision surgery. Radiographic changes have been reported to occur in the proximal femur of impacted cancellous allografts, and an increase and decrease in these radiographic findings are considered to be due to the primary restoration and re-permeation of blood flow. Secondary bone remodeling means that the CPT stem is engaged in the cement because of the continuous stress, and the load is transferred to the morselized cancellous allograft such that the compression force is constantly applied to the bone cement. In our study, trabecular remodeling and cortical bone repair were not confirmed histologically; however, trabecular remodeling (82.1%) and cortical bone repair (53.6%) were observed in radiographic shadow changes in the impacted bone. Femoral fractures during IBG are an important problem associated with the dissociation of the stem, which requires revision.[21] Elting et al.[18] reported that a structural allograft should be considered if there is a

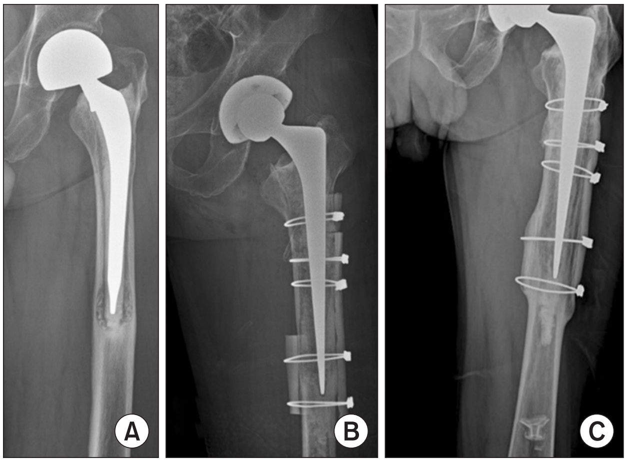

Fig. 2. (A) Preoperative radiograph of a 66-year-old man with widening of the medullary canal and severe bone loss. (B) Postoperative radiograph of reconstruction using a strut allograft and morselized impaction grafting with a standard cemented stem. (C) Radiograph taken at 12 years showed incorporation of the morselized allograft and cortical healing of the strut allograft. Subsidence was observed to be less than 2 mm with no loosening and no osteolysis.

high probability of fracture due to a cortical bone defect or low thickness of the bone. In this study, if the bone defect of the proximal femur was severe, the non-containment was made to be containment. Structural bone grafting was performed to prevent fractures during compression grafting (Fig. 2). When attempting revision THA in patients with severe bone loss or in cases where firm fixation with the femoral stem at periprosthetic fracture is challenging, cortical strut allografting may improve structural support.[22] Wilson et al.[23] reported that impacted allografts contribute to the process of remodeling and incorporation of bone. Cho et al.[24] reported satisfactory initial stability in surgery performed with an impacting bone graft, and this stable fixation was maintained at mid-term follow-up. In our cases, structural bone grafting was performed due to intraoperative fracture, and radiological findings revealed cortical bone union.

The CPT stem has a wide proximal end and a thin tip, and subsidence occurs in the bone cement for torsional stability and increased compression force between the bone and cement. To cause subsidence, bone cement is characterized by gradual creep due to repeated compressive load and hoop stress over time and stress relaxation due to continuous strain. The CPT stem was found to subside within 1–2 years of THA and THA revision. Elting et al.[18] reported an average of 2.8 mm subsidence occurred in 48% of 56 patients, and Gie et al.[11] reported that an average of 6.1 mm subsidence occurred inside the bone cement in 79% of 56 patients. However, Masterson et al.[25] concluded that failure of the femoral stem may result in premature subsidence of more than 10 mm within 6 months due to fracture of the thinner cement mantle. In our study, 78.6% of the cases had subsidence within 5 mm of the bone cement, and more than 10 mm of subsidence occurred in 1 case; however, no stem failure or fracture of the bone cement mantle occurred during follow-up. Furthermore, Karrholm et al.[26] reported that cement that did not reach the tip of the stem sufficiently was the most common defect in the instability of the stem. The limitation of this study is that it is a relatively small, single-center study. In the future, multicenter prospective studies that include many patients are expected to be needed.

In conclusion, IBG and the use of a standard cemented polished stem for femoral revision arthroplasty can be considered successful methods to reconstruct extended bone defects and to provide initial stability of the cemented femoral stem when the stability of cementless femoral stems is not achieved. However, a biomechanical understanding of the CPT stem and surgical technique to obtain a sufficient amount of graft compression and mechanical stability should be required.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGEMENTS

This research was supported by a grant from Wonkwang University in 2022.

ORCID

Jin Sung Park https://orcid.org/0000-0002-8905-9257
Seok Hyun Kweon https://orcid.org/0000-0003-1939-2676
Sung Ju Kang https://orcid.org/0000-0003-1826-295X
Yang Hun Jo https://orcid.org/0000-0002-3044-6295

REFERENCES

1. Sporer SM, Paprosky WG. Revision total hip arthroplasty: the limits of fully coated stems. Clin Orthop Relat Res. 2003;

417:203-9.

2. Eldridge JD, Smith EJ, Hubble MJ, Whitehouse SL, Learmonth ID. Massive early subsidence following femoral impaction grafting. J Arthroplasty. 1997;12(5):535-40.
3. Leopold SS, Berger RA, Rosenberg AG, Jacobs JJ, Quigley LR, Galante JO. Impaction allografting with cement for revision of the femoral component: a minimum four-year follow-up study with use of a precoated femoral stem. J Bone Joint Surg Am. 1999;81(8):1080-92.
4. Pekkarinen J, Alho A, Lepisto J, Ylikoski M, Ylinen P, Paavilainen T. Impaction bone grafting in revision hip surgery: a high incidence of complications. J Bone Joint Surg Br. 2000;82(1):103-7.
5. Linder L. Cancellous impaction grafting in the human femur: histological and radiographic observations in 6 autopsy femurs and 8 biopsies. Acta Orthop Scand. 2000;71(6):543-52.
6. Mikhail WE, Weidenhielm LR, Wretenberg P, Mikhail N, Bauer TW. Femoral bone regeneration subsequent to impaction grafting during hip revision: histologic analysis of a human biopsy specimen. J Arthroplasty. 1999;14(7):849-53.
7. Nelissen RG, Bauer TW, Weidenhielm LR, LeGolvan DP, Mikhail WE. Revision hip arthroplasty with the use of cement and impaction grafting. histological analysis of four cases. J Bone Joint Surg Am. 1995;77(3):412-22.
8. Ullmark G, Linder L. Histology of the femur after cancellous impaction grafting using a Charnley prosthesis. Arch Orthop Trauma Surg. 1998;117(3):170-2.
9. Engelbrecht E, Heinert K. Klassifikation und behandlungsrichtlinien von knochensubstanzverlusten bei revisionsoperationen am hüftgelenk. In: Engelbrecht E, Heinert K, eds. Primär- und revisions-alloarthroplastik hüft- und kniegelenk. Berlin: Springer; 1987. 189-201.
10. Gruen TA, McNeice GM, Amstutz HC. "Modes of failure" of cemented stem-type femoral components: a radiographic analysis of loosening. Clin Orthop Relat Res. 1979;(141):17-27.
11. Gie GA, Linder L, Ling RS, Simon JP, Slooff TJ, Timperley AJ. Impacted cancellous allografts and cement for revision total hip arthroplasty. J Bone Joint Surg Br. 1993;75(1):14-21.
12. Ornstein E, Linder L, Ranstam J, Lewold S, Eisler T, Torper M. Femoral impaction bone grafting with the Exeter stem: the Swedish experience. Survivorship analysis of 1305 revisions performed between 1989 and 2002. J Bone Joint Surg Br. 2009;91(4):441-6.
13. Wraighte PJ, Howard PW. Femoral impaction bone allografting with an Exeter cemented collarless, polished, tapered stem in revision hip replacement: a mean follow-up of 10.5 years. J Bone Joint Surg Br. 2008;90(8):1000-4.
14. Leopold SS, Jacobs JJ, Rosenberg AG. Cancellous allograft in revision total hip arthroplasty: a clinical review. Clin Orthop Relat Res. 2000;(371):86-97.
15. Garcia-Cimbrelo E, Garcia-Rey E, Cruz-Pardos A. The extent of the bone defect affects the outcome of femoral reconstruction in revision surgery with impacted bone grafting: a five- to 17-year follow-up study. J Bone Joint Surg Br. 2011; 93(11):1457-64.
16. Schreurs BW, Huiskes R, Slooff TJ. The initial stability of cemented and non-cemented femoral stems fixated with a bone grafting technique. Clin Mater. 1994;16(2):105-10.
17. Schreurs BW, Arts JJ, Verdonschot N, Buma P, Slooff TJ, Gardeniers JW. Femoral component revision with use of impaction bone-grafting and a cemented polished stem. J Bone Joint Surg Am. 2005;87(11):2499-507.
18. Elting JJ, Mikhail WE, Zicat BA, Hubbell JC, Lane LE, House B. Preliminary report of impaction grafting for exchange femoral arthroplasty. Clin Orthop Relat Res. 1995; (319): 159-67.
19. Lee JM, Kim TH. Acetabular cup revision arthroplasty using morselized impaction allograft. Hip Pelvis. 2018;30(2):65-77.
20. Ling RS, Timperley AJ, Linder L. Histology of cancellous impaction grafting in the femur: a case report. J Bone Joint Surg Br. 1993;75(5):693-6.
21. Oakes DA, Cabanela ME. Impaction bone grafting for revision hip arthroplasty: biology and clinical applications. J Am Acad Orthop Surg. 2006;14(11):620-8.
22. Park JS, Moon KH. Medium- to long-term results of strut allografts treating periprosthetic bone defects. Hip Pelvis. 2018;30(1):23-8.
23. Wilson MJ, Hook S, Whitehouse SL, Timperley AJ, Gie GA. Femoral impaction bone grafting in revision hip arthroplasty: 705 cases from the originating centre. Bone Joint J. 2016; 98B(12):1611-9.
24. Cho YJ, Kwak SJ, Chun YS, Rhyu KH, Ko TS, Yoo MC. Revision total hip arthroplasty using a fully porous-coated long stem: a minimum 5 years follow up. J Korean Hip Soc. 2010;22(3):189-96.
25. Masterson EL, Masri BA, Duncan CP. The cement mantle in the Exeter impaction allografting technique: a cause for concern. J Arthroplasty. 1997;12(7):759-64.
26. Karrholm J, Hultmark P, Carlsson L, Malchau H. Subsidence of a non-polished stem in revisions of the hip using impaction allograft: evaluation with radiostereometry and dual-energy X-ray absorptiometry. J Bone Joint Surg Br. 1999; 81(1):135-42.