Total Hip Arthroplasty Using Modular Trabecular Metal Acetabular Components for Failed Treatment of Acetabular Fractures: A Mid-term Follow-up Study

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Abstract

Background: Porous-coated cups have been widely used in acetabular reconstruction after failed treatment of acetabular fractures, and good results have been reported with the use of these cups; however, the durability and functionality of modular trabecular metal (TM) acetabular components in acetabular reconstruction after failed treatment of acetabular fractures remain unclear. This study aimed to examine the radiographic and clinical outcomes associated with the use of modular TM acetabular components for failed treatment of acetabular fractures to assess the durability and functionality of these components in acetabular reconstruction after failed treatment of acetabular fractures.

Methods: A total of 41 patients (41 hips) underwent total hip arthroplasty (THA) using modular TM acetabular components for failed treatment of acetabular fractures at our hospital between January 2007 and December 2012. Among these patients, two were lost to follow-up. Therefore, 39 patients (39 hips) were finally included in this study. The Harris hip score before and after the surgery, satisfaction level of the patients, and radiographic results were assessed.

Results: The mean Harris hip score increased from 34 (range, 8–52) before surgery to 91 (range, 22–100) at the latest follow-up examination (P < 0.001). The results were excellent for 28 hips, good for six, fair for three, and poor for two. Among the 39 patients, 25 (64%) and 10 (26%) were very satisfied and somewhat satisfied, respectively. All cups were found to be fully incorporated, and no evidence of cup migration or periacetabular osteolysis was noted.

Conclusions: Despite the technically demanding nature of the procedure, THA using modular TM acetabular components showed good durability and functionality and may be an effective reconstruction option for failed treatment of acetabular fractures.

Key words: Acetabular Fracture; Trabecular Metal; Total Hip Arthroplasty

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Introduction

Acetabular fractures after high-energy trauma are serious and uncommon orthopedic injuries that can have late complications, such as posttraumatic arthritis and avascular necrosis of the femoral head. Total hip arthroplasty (THA) is an effective surgical option to relieve pain and restore function after failed treatment of acetabular fractures. Previous studies have demonstrated encouraging outcomes with regard to cementless porous-coated acetabular components. Trabecular metal (TM) (Zimmer Corp., Warsaw, IN, USA) is a porous material made of tantalum, with a high coefficient of friction of 0.98 and a high porosity of 80%. It has excellent biocompatibility and safety, with the inherent advantages of maximum initial stability and quick and safe patterns of bone ingrowth and soft tissue vascularization. A series of histological and clinical studies have reported that TM cups show rapid infiltration with healing of fibrous and osseous tissues as well as early mechanical stability. Although the results of monoblock and revision TM acetabular components in complex primary and revision THA conditions are
encouraging, the durability and functionality of modular TM acetabular components in acetabular reconstruction after failed treatment of acetabular fractures remain unclear.

We hypothesized that modular TM acetabular components may provide good long-term reconstruction for irregular acetabula after failed treatment of acetabular fractures in selected cases. The purpose of this study was to examine the radiographic and clinical outcomes associated with the use of modular TM acetabular components for failed treatment of acetabular fractures to assess the durability and functionality of these components in acetabular reconstruction after failed treatment of acetabular fractures.

**Methods**

**Patient demographics**

A total of 41 patients (41 hips) underwent THA using modular TM acetabular components for failed treatment of acetabular fractures at our hospital between January 2007 and December 2012. Among the 41 patients, two were lost to follow-up. Therefore, 39 patients (39 hips) were finally included in the present study [Table 1]. We also reviewed 42 consecutive patients (44 hips) treated with a titanium hemispheric component reconstruction for failed treatment of acetabular fractures at our hospital between 1998 and 2007 as a control group [Table 1].

**Surgical technique**

All hips in both groups were exposed through a posterolateral approach. We did not intend to remove any instruments unless they were interfering with the reaming and fixation of the acetabular cup. In all cases, the initial stability and orientation of the cup were confirmed with intraoperative radiographs. In all hips, 2–3 screws were used with the cups to enhance their initial stability.

We used the highly cross-linked polyethylene (PE) liner longevity PE (Zimmer Corp., Warsaw, IN, USA) in the group using a tantalum cup, with a standard offset and an elevation of 10°. The mean diameter of the TM shells was 50.7 mm (range, 44–60 mm). We used shells equal to or smaller than 48 mm and corresponding 28-mm femoral heads in 13 patients and shells equal to or larger than 50 mm and corresponding 32-mm femoral heads in 26 patients. In all hips, Biolox Forte (CeramTec, Plochingen, Germany) AlO₃ femoral heads and cementless stems were used. In the group using a titanium cup, we used a ceramic-on-ceramic bearing surface in nine hips, a ceramic-on-PE bearing surface in 20 hips, and cobalt-chrome heads on a PE bearing surface in 15 hips, with corresponding 28-mm femoral heads in all patients.

**Postoperative rehabilitation**

Starting on the 2nd postoperative day, the patients in the tantalum cup group were mobilized with toe-touch weight-bearing on crutches for the first 2 weeks, followed by partial weight-bearing in the 3rd week, full weight-bearing with crutches after 6 weeks, and discontinuation of the use of crutches at 8–12 weeks after THA. In the titanium cup group, patients were allowed toe-touch weight-bearing with crutches for 6 weeks, and then they advanced to 50% weight-bearing as tolerated with crutches for 6 weeks.

**Evaluation of outcomes**

All patients were routinely examined at 3 months, 6 months, 1 year, 2 years, and then every 2 years thereafter. All clinical and radiographic results were reviewed by one of the authors who was not involved in patient care. Clinical outcomes were evaluated using the Harris hip scoring system. The Harris hip score is based on an assessment of pain, function, deformities, and range of motion. On a 100-point scale, a score of 90 points or more is considered as an excellent outcome; 80–89 points, a good outcome; 70–79 points, a fair outcome; and 70 points or less, a poor outcome.

Serial radiographs included anteroposterior, lateral, and two 45° oblique views of the involved hip. Computed tomography images of the involved pelvis were routinely reviewed. Radiographic assessments of the acetabular components were performed in the three zones proposed by DeLee and Charnley. The presence and extent of radiolucent lines were evaluated using the criteria of Callaghan and Charnley. Radiographic failure was determined by a periacetabular gap, which often indicates incomplete seating of acetabular components. At the follow-up visits, we recorded whether the gap resolved, persisted, or expanded and when these occurred. Radiographic failure was determined by a vertical or horizontal migration of over 3 mm, a change in the inclination angle of over 5°, and the presence of fewer than two signs of osteointegration, according to the Moore criteria.

![Table 1: Patient characteristics](image-url)
Heterotopic ossification (HO) was categorized according to the classification system of Brooker et al. All patients were administered indomethacin after surgery (25 mg twice a day for 4 weeks) as prophylaxis against HO.

The present study was approved by the institutional review board of our hospital and was performed in accordance with the guidelines of the Helsinki Declaration.

Statistical analysis
The preoperative and final follow-up Harris hip scores were compared using the Mann–Whitney signed rank test. All analyses were performed using SPSS software for Windows (version 15.0; IBM, Armonk, NY, USA). A P value < 0.05 was considered statistically significant.

RESULTS
Patient characteristics
The patient characteristics are presented in Table 1. The mean age of the patients at the time of THA in the group using tantalum cup was 47.3 years (range, 22–70 years), and the mean body mass index was 25.7 kg/m² (range, 17.5–35.6 kg/m²). The mean duration of follow-up was 58.4 months (range, 25–101 months). According to the initial fracture pattern classification system of Judet et al., 29 (74%) hips had simple fracture patterns (posterior-wall fractures, 27 [69%]; transverse fractures, 2 [5%]) and 10 (26%) hips had complex fracture patterns (transverse plus posterior-wall fractures, 4 [10%]; posterior column plus posterior wall fractures, 3 [8%]; double column fractures, 2 [5%]; and T-shape fractures, 1 [3%]). According to the criteria for acetabular bone defects proposed by the American Academy of Orthopaedic Surgeons, 14 hips had type I segmental acetabular defects, eight had type II cavitary defects, six had type III combined defects, and one had type IV pelvic discontinuity. Among the 39 patients, 21 received acetabular bone grafts (18 received morcellized autografts and three received bulk autografts).

In the titanium cup group, 26 (59%) hips had simple fracture patterns and 18 (41%) hips had complex fracture patterns. Moreover, 19 hips had type I defects, seven had type II defects, and seven had type III combined defects. In all patients in both groups, the degree of cup coverage by the host bone was over 70%.

Clinical assessment
In the group using TM cups, the mean Harris hip score increased from 34 (range, 8–52) before surgery to 91 (range, 22–100) at the latest follow-up examination (P < 0.001). The results were excellent for 28 hips, good for six, fair for three, and poor for two. Regarding postoperative pain, 33 patients had no pain, two had mild pain, two had moderate pain, and two had severe pain. In addition, 14 (36%) patients had a limp. Among the 39 patients, 25 (64%), 10 (26%), 2 (5%), and 2 (5%) patients were very satisfied, somewhat satisfied, somewhat dissatisfied, and very dissatisfied, respectively, with the results of the procedure.

These results compared favorably with those in the control group treated with a titanium component, in which the average Harris hip score improved from an average of 49.5 points to an average of 90.1 points (P < 0.05), and 80% of the patients had a good or excellent result.

Radiographic results
All TM cups were found to be fully incorporated, and no evidence of cup migration or periacetabular osteolysis was noted. Periacetabular gaps were observed on immediate postoperative radiographs in 10 (25.6%) hips. The gap persisted without any change in location and width in only one patient and the gaps in the other patients resolved within one year after THA. At the latest follow-up, new onset radiolucency was noted in one hip, and it was located in zone 1 and had a width of <1 mm. No acetabular screw breakage was noted in any of the patients.

In the control group, postoperative periacetabular gaps were observed in seven hips. All of these gaps, but three, disappeared within the initial 14 months after THA. The new onset radiolucency was noted in three hips. In two, the radiolucency was <1 mm wide, and in one, it was more than 2 mm wide. All of them were associated with a good or excellent Harris hip score and were considered stable.

Complications
In the group using TM cups, perioperative complications included one iatrogenic sciatic nerve injury in a patient with posterior wall fracture and periprosthetic infection in two patients. The patient with sciatic nerve injury was treated with methylprednisolone injection and dorsal extension orthosis, and partial resolution was noted within one year. In the two patients with periprosthetic infection, microbial culture tests were used to confirm infection. Both patients had undergone open reduction and internal fixation (ORIF) for their initial posterior wall fractures, and they were treated with initial implant removal, irrigation, and debridement. The two cups and stems were stable at the time of removal. Unfortunately, both patients refused to undergo further THA revision. Among the study patients, no patient needed revision because of aseptic loosening.

After surgery, 6 (15.4%) hips demonstrated HO with no adverse clinical effects. Of these six hips, three had Brooker class I HO, two had class II HO, and one had class III HO. No patient required further procedures for HO.

In the control group, perioperative complications included one dislocation and three sciatic nerve injuries. After surgery, 16 hips (31%) demonstrated HO with no adverse clinical effects. Seven hips (14%) had Brooker class I HO, 6 (12%) had class II HO, and 3 (6%) had class III HO.

DISCUSSION
THA is an effective surgical option to relieve pain and restore function after failed treatment of acetabular fractures. Romness and Lewallen reported a failure rate of 50% at 10 years for cemented fixation, which is not currently
recommended. In recent years, many authors have suggested the use of cementless porous-coated components to reconstruct acetabular fractures after failed treatment and have emphasized its advantages for excellent prosthetic survival. Our study also demonstrated that THA using TM acetabular components for failed treatment provided excellent fixation, with a low complication rate and a high level of patient satisfaction.

The majority of clinical and radiographic studies of TM acetabular components in primary THA have focused on the use of monoblock acetabular cups with direct compression-molded ultra-high-molecular-weight PE liners, and these studies have consistently reported successful early and mid-term results with these components. The advantages of a monoblock elliptical cup include elimination of backside wear as a source of PE debris and blockage of the potential pathways that allow debris to enter the periacetabular region of the pelvis, resulting in a low incidence of aseptic loosening.

There are several advantages in the use of a modular TM cup instead of a monoblock TM cup for failed treatment of acetabular fractures. First, at the time of surgery, residual pelvic deformities can lead to distortion of the anatomy and a sclerotic or deficient host bone bed that may reduce the initial stability of acetabular components. The cluster-hole shell in a modular THA cup provides the option of using dome screws for adjunctive fixation and, in the present study, two to three screws were used in all cups. Second, initial trauma and subsequent ORIF may predispose hips to a high risk of instability. With the modular TM cup, a liner with the appropriate elevation can be used to optimize the femoral head coverage and prevent dislocation. Intraoperatively, we used a liner with an elevation of 10°. Accordingly, taking account of enhanced intraoperative stability and quick bone ingrowth, after THA, our patients were allowed to recover their full weight-bearing earlier when compared to the patients treated with a titanium component reconstruction. Third, patients with acetabular fractures are generally young and have monoarticular arthrosis that results from a high activity level. In the present study, the mean age of the patients at the time of THA was only 47.3 years (range, 22–70 years), and wear of the PE liner and associated osteolysis were issued. The modular TM cup allows the use of the highly cross-linked PE liner longevity PE; this liner has been shown to have a substantially low wear rate in laboratory studies and clinical follow-up reports. However, if the problem of wear occurs, the liner can be easily changed. Kamada et al. reported the clinical results of modular TM cups used in 45 dysplastic hips at a mean follow-up period of 9.8 years. In their study, the mean Japanese Orthopaedic Association hip score improved from 48.2 preoperatively to 92.1 at the most recent follow-up. In addition, all cups were radiographically stable with no evidence of progressive radiolucency or osteolysis, regardless of bone grafting, and no cup needed revision surgery.

In our study, all cups were found to be fully incorporated, and no evidence of cup migration or periacetabular osteolysis was noted. We observed periacetabular gaps on immediate postoperative radiographs in 10 hips and, of these 10 hips, nine showed resolution of the gaps within one year after THA. New onset radiolucency was detected in one hip. Our radiographic findings are in accordance with the findings reported by Gruen et al. and Macheras et al. who used a monoblock cup, Kamada et al. who used a modular cup, and Noiseux et al. who used a hybrid monoblock and modular cup. Gruen et al. reported the results of monoblock cups used in 414 primary cases at a minimum follow-up of two years. In their study, 80 hips had postoperative radiolucent gaps, and the gaps were completely filled in 67 of the 80 hips (84%) at the most recent follow-up. In addition, no new radiolucent line, progression of any gap, osteolysis, or aseptic loosening requiring revision was noted. Macheras et al. and Kamada et al. reported the similar results.

In the present study, only cluster-hole TM shells were implanted. The component has a hemiellipsoid geometry, and the equatorial diameter is 2 mm larger than the polar diameter, allowing for an initial 2-mm press-fit with line-to-line reaming. This maximizes bone contact and enhances initial stability. Compared with the group of titanium cup, more serious bone defects cases were noted in the group using TM cups (six had type III combined defects, and one had type IV pelvic discontinuity), which clinically confirms the availability of TM cups in complex circumstances of acetabular reconstruction.

Use of TM acetabular components for reconstruction after failed treatment of acetabular fractures is technically challenging as evidenced by the results of our study. Several factors should be considered when performing THA using TM acetabular components for failed treatment of acetabular fractures, including the presence of instruments and necrotic or deficient bone, fracture nonunion, ankylosis, scarring and tethering of the sciatic nerve, and risk of infection.

In patients who have undergone previous ORIF, infection should be ruled out before performing THA. Appropriate baseline tests include assessment of the erythrocyte sedimentation rate and C-reactive protein level. If these values are abnormal or if there is a high suspicion of infection despite normal laboratory values, aspiration of the hip joint should be performed. The fluid should be analyzed for synovial cell count with differential, and aerobic and anaerobic microorganisms. If infection is confirmed, the surgery should be performed in stages. In the first stage, any residual implants should be removed and debridement of the hip joint should be performed, including removal of all cartilage, followed by placement of an antibiotic-loaded spacer. In the second stage, revision should be performed after confirming eradication of the infection. The choice of intravenous or oral antibiotics depends on the results of intra- and post-operative cultures.
Cementless acetabular reconstruction after

Radiographs of a 40-year-old woman who underwent second-stage operation showing reconstruction with trabecular metal and placement of an antibiotic spacer. (d) Radiograph obtained at the end of the acetabular fracture. (c) Radiograph obtained at the first-stage arthritis, avascular necrosis of the femoral head, and improper union after open reduction and internal fixation showing posttraumatic infection. (a) Radiograph showing acetabular and femoral head two-stage reconstruction owing to arthritis, avascular necrosis, and improper union of the acetabular fracture. (b) Radiograph obtained one year after open reduction and internal fixation showing posttraumatic arthritis, avascular necrosis of the femoral head, and improper union of the acetabular fracture. (c) Radiograph obtained at the first-stage operation showing removal of all instruments because of infection and placement of an antibiotic spacer. (d) Radiograph obtained at the second-stage operation showing reconstruction with trabecular metal acetabular components and a porous-coated stem.

Figure 1: Radiographs of a 40-year-old woman who underwent two-stage reconstruction owing to arthritis, avascular necrosis, and infection. (a) Radiograph showing acetabular and femoral head fractures after high-energy trauma. (b) Radiograph obtained one year after open reduction and internal fixation showing posttraumatic arthritis, avascular necrosis of the femoral head, and improper union of the acetabular fracture. (c) Radiograph obtained at the first-stage operation showing removal of all instruments because of infection and placement of an antibiotic spacer. (d) Radiograph obtained at the second-stage operation showing reconstruction with trabecular metal acetabular components and a porous-coated stem.

The present study presented several limitations. First, this was a retrospective study and not a prospective randomized study, which increased the possibility of selection bias. Second, the number of patients in the study was relatively small, and further studies involving more participants are anticipated. Finally, the follow-up duration was relatively short, and a long-term follow-up study should be performed in the future.

In conclusion, despite the technically demanding nature of the procedure, THA using modular TM acetabular components showed good durability and functionality and may be an effective reconstruction option for failed treatment of acetabular fractures. TM acetabular components can provide immediate stable macrofixation and an environment for optimum biological microfixation. Good functional outcome and prosthetic survival can be expected with THA using modular TM acetabular components in patients with failed treatment of acetabular fractures.

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Conflicts of interest

There are no conflicts of interest.

References

1. Daurka JS, Pastides PS, Lewis A, Rickman M, Bircher MD. Acetabular fractures in patients aged > 55 years: A systematic review of the literature. Bone Joint J 2014;96-B:157-63. doi: 10.1302/0301-620X.96B2.32979.
2. Sierra RJ, Mabry TM, Sems SA, Berry DJ. Acetabular fractures: The role of total hip replacement. Bone Joint J 2013;95-B 11 Suppl A:11-6. doi: 10.1302/0301-620X.95B11.32897.
3. Jouffroy P; Bone and Joint Trauma Study Group (GETRAUM). Indications and technical challenges of total hip arthroplasty in the elderly after acetabular fracture. Orthop Traumatol Surg Res 2014;100:193-7. doi: 10.1016/j.otsr.2014.01.001.
4. Huo MH, Solberg BD, Zatorski LE, Keaggi KJ. Total hip replacements done without cement after acetabular fractures: A 4- to 8-year follow-up study. J Arthroplasty 1999;14:827-31.
5. Bellabarba C, Berger RA, Bentley CD, Quigley LR, Jacobs JJ, Rosenberg AG, et al. Cementless acetabular reconstruction after acetabular fracture. J Bone Joint Surg Am 2001;83-A:968-76.
6. Berry DJ, Halasy M. Un cemented acetabular components for arthritis after acetabular fracture. Clin Orthop Relat Res 2002;405:164-7.
7. Ranawat A, Zelken J, Helfet D, Buly R. Total hip arthroplasty for posttraumatic arthritis after acetabular fracture. J Arthroplasty 2009;24:759-67. doi: 10.1016/j.arth.2008.04.004.
8. Zhang L, Zhou Y, Li Y, Xu H, Guo X, Zhou Y. Total hip arthroplasty for failed treatment of acetabular fractures: A 5-year follow-up study. J Arthroplasty 2011;26:1189-93. doi: 10.1016/j.arth.2011.02.024.
9. Rahbek O, Kold S, Zipper B, Overgaard S, Soballe K. Particle migration and gap healing around trabecular metal implants. Int Orthop 2005;29:368-74.
10. Meneghini RM, Ford KS, McCollough CH, Hanssen AD, Lewallen DG. Bone remodeling around porous metal cementless acetabular components. J Arthroplasty 2010;25:741-7. doi: 10.1016/j.arth.2009.04.025.
11. Gruen TA, Poggie RA, Lewallen DG, Hanssen AD, Lewis RJ, O’Keefe TJ, et al. Radiographic evaluation of a monoblock acetabular component: A multicenter study with 2- to 5-year results. J Arthroplasty 2005;20:369-78.
12. Joglekar SB, Rose PS, Lewallen DG, Sim FH. Tantalum acetabular cups provide secure fixation in THA after pelvic irradiation at minimum 5-year followup. Clin Orthop Relat Res 2012;470:3041-7. doi: 10.1007/s11999-012-2382-8.
13. Macheras GA, Kateros K, Koutsostathis DS, Tsakotos G, Galanakos S, Papadakis SA. The trabecular metal monoblock acetabular component in patients with high congenital hip dislocation: A prospective study. J Bone Joint Surg Br 2010;92:624-8. doi: 10.1302/0301-620X.92B5.23256.
14. Abolghasemian M, Tangsataporn S, Sternheim A, Backstein D, Safir O, Gross AE. Combined trabecular metal acetabular shell and augment for acetabular revision with substantial bone loss: A mid-term review. Bone Joint J 2013;95-B:166-72. doi: 10.1302/0301-620X.95B2.30608.
15. Siegmeth A, Duncan CP, Masri BA, Kim WY, Garbus DZ. Modular tantalum augment for acetabular defects in revision hip arthroplasty. Clin Orthop Relat Res 2009;467:199-205. doi: 10.1007/s11999-008-0549-0.
16. Sporer SM, Paprosky WG. The use of a trabecular metal acetabular component and trabecular metal augment for severe acetabular defects. J Arthroplasty 2006;21 6 Suppl 2:83-6.
17. Judet R, Judet J, Letoarnel E. Fractures of the acetabulum: Classification and surgical approaches for open reduction. Preliminary report. J Bone Joint Surg Am 1964;46:1615-46.
18. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: Treatment by mold arthroplasty. An end-result study using a new method of result evaluation. J Bone Joint Surg Am 1969;51:737-55.
19. Callaghan JJ, Dysart SH, Savory CG. The uncemented porous-coated anatomic total hip prosthesis. Two-year results of a prospective consecutive series. J Bone Joint Surg Am 1988;70:337-46.
20. Noiseux NO, Long WJ, Mabry TM, Hansen AD, Lewallen DG. Uncemented porous tantalum acetabular components: Early follow-up and failures in 613 primary total hip arthroplasties. J Arthroplasty 2014;29:617-20. doi: 10.1016/j.arth.2013.07.037.
21. Moore MS, McAuley JP, Young AM, Engh CA Sr. Radiographic signs of osseointegration in porous-coated acetabular components. Clin Orthop Relat Res 2006;444:176-83.
22. Brooker AF, Bowerman JW, Robinson RA, Riley LH Jr. Ectopic ossification following total hip replacement. Incidence and a method of classification. J Bone Joint Surg Am 1973;55:1629-32.
23. Romness DW, Lewallen DG. Total hip arthroplasty after fracture of the acetabulum. Long-term results. J Bone Joint Surg Br 1990;72:761-4.
24. Macheras G, Kateros K, Kostakos A, Koutsostathis S, Danomaras D, Papagelopoulos PJ. Eight- to ten-year clinical and radiographic
outcome of a porous tantalum monoblock acetabular component. J Arthroplasty 2009;24:705-9. doi: 10.1016/j.arth.2008.06.020.

25. Muratoglu OK, Bragdon CR, O’Connor DO, Jasty M, Harris WH. A novel method of cross-linking ultra-high-molecular-weight polyethylene to improve wear, reduce oxidation, and retain mechanical properties. Recipient of the 1999 HAP Paul Award. J Arthroplasty 2001;16:149-60.

26. Lee JH, Lee BW, Lee BJ, Kim SY. Midterm results of primary total hip arthroplasty using highly cross-linked polyethylene: Minimum 7-year follow-up study. J Arthroplasty 2011;26:1014-9. doi: 10.1016/j.arth.2011.03.015.

27. Thomas GE, Simpson DJ, Mehmood S, Taylor A, McLardy-Smith P, Gill HS, et al. The seven-year wear of highly cross-linked polyethylene in total hip arthroplasty: A double-blind, randomized controlled trial using radiostereometric analysis. J Bone Joint Surg Am 2011;93:716-22. doi: 10.2106/JBJS.J.00287.

28. Kamada T, Mashima N, Nakashima Y, Imai H, Takeba J, Miura H. Mid-term clinical and radiographic outcomes of porous tantalum modular acetabular components for hip dysplasia. J Arthroplasty 2015;30:607-10. doi: 10.1016/j.arth.2014.11.007.

29. Macheras GA, Papagelopoulos PI, Kateros K, Kostakos AT, Baltas D, Karachalios TS. Radiological evaluation of the metal-bone interface of a porous tantalum monoblock acetabular component. J Bone Joint Surg Br 2006;88:304-9.