



# Risk Factors and Outcomes Associated with Intraoperative Fractures during Short-Stem Total Hip Arthroplasty for Osteonecrosis of the Femoral Head

Rajesh Malhotra, MS, Saurabh Gupta, MS, Vivek Gupta, MD\*, Vikrant Manhas, MS

*Department of Orthopedics, All India Institute of Medical Sciences (AIIMS), Teaching Block, New Delhi,*

*\*Department of Community Ophthalmology, All India Institute of Medical Sciences (AIIMS), New Delhi, India*

**Background:** Young age in osteonecrosis of the femoral head (ONFH) demands bone-preserving, short-stem arthroplasty. Several designs including neck-preserving stems and neck-resecting, shortened, standard stems are classified as short stems. There is a paucity of literature investigating risk factors and outcomes of intraoperative complications of neck preserving, short-stem arthroplasty in ONFH.

**Methods:** A total of 107 hips operated with METHA short-stem arthroplasty for ONFH were retrospectively evaluated. The mean age of patients was 43.7 years (range, 27–60 years). Nine patients had an intraoperative fracture. Seven hips received prophylactic cerclage wiring for poor bone quality. Patients were invited for clinical and radiological evaluation at the latest follow-up.

**Results:** The mean follow-up of patients was 47.2 months. Significant association with intraoperative fractures and the need for prophylactic cerclage wiring were found in steroids-, alcohol-, and chronic renal failure-induced ONFH. However, patient sex, body mass index, traumatic/idiopathic ONFH, previous implant *in situ*, prosthesis size, and single-sitting bilateral total hip replacement (THA) were not the risk factors. All hips showed signs of osteointegration at final follow-up. No revision was done during the study period for any cause.

**Conclusions:** METHA short-stem THA offers excellent functional and radiological outcomes in ONFH. However, precaution must be exercised in patients with steroids-, alcohol-, and renal disorders-induced ONFH due to poor bone quality and higher chances of intraoperative fractures. Also, additional measures such as the use of a high-speed burr and prophylactic cerclage wiring in ONFH may allow predictable and safe use of short stems.

**Keywords:** Hip, Osteonecrosis, Femur head necrosis, Arthroplasty, Short stem arthroplasty

Total hip replacement (THA) is an established procedure with excellent long-term results.<sup>1)</sup> In recent years, it has been used increasingly in young patients with age less than

60 years.<sup>2)</sup> By the year 2030, it is estimated that more than 25% of all THA will be performed in patients under the age of 55.<sup>3)</sup> Young patients beset hip surgeons to think of bone preserving alternatives in THA for a foreseen revision surgery.<sup>4)</sup> Short stems were introduced considering this disquiet.<sup>4)</sup> They are specifically less than 12 cm in length and are bone-preserving because of the more proximal anchor and no proximal stress shielding compared to standard length stems.<sup>5)</sup> Today, short-stem hip arthroplasty is an accepted procedure with mid-term results comparable to those of standard length THA.<sup>1,4,5)</sup>

Received March 12, 2021; Revised June 10, 2021;

Accepted July 6, 2021

Correspondence to: Vikrant Manhas, MS

Department of Orthopedics, All India Institute of Medical Sciences (AIIMS), Teaching Block, New Delhi 110029, India

Tel: +91-90-13976326, Fax: +91-11-26589093

E-mail: vikrantorthoaiims@gmail.com

Osteonecrosis of the femoral head (ONFH) is a common indication for THA in young adults.<sup>6)</sup> It has been closely investigated because of the historically lower survivorship of standard length THA in ONFH.<sup>7,8)</sup> These outcomes are blamed on the disease pathophysiology leading to inferior bone quality and altered bone metabolism up to the metaphyseal region of the proximal femur.<sup>9,10)</sup> The advances in material and manufacturing process of implants in the last two decades led to comparable results and similar survivorship of standard length THA in ONFH compared to other indications.<sup>11)</sup> Even though the young age in ONFH demands short-stem arthroplasty, anchoring the short stem within or close to the pathological bone may affect osteointegration and survival of prostheses.<sup>4,9,12)</sup> Several designs including neck-preserving stems and neck-resecting, shortened, standard stems are classified as short stems.<sup>4)</sup> They have encouraging outcomes in terms of function and mid-term survival.<sup>2,4-6,12)</sup> However, there is a paucity of literature investigating specific risk factors and outcomes of intraoperative complications of neck-preserving short stems in ONFH.<sup>6,12)</sup> Therefore, this study was proposed to evaluate METHA neck-preserving stem (Aesculap AG, Tuttlingen, Germany) for THA in terms of complications, functional outcome, and survival.

## METHODS

This retrospective study reviewed the clinical and radiological outcomes of THA with METHA short-stem prostheses in young patients with ONFH. The study was approved by the Institutional Ethics Committee of All India Institute of Medical Sciences (IEC-62/09.03.2018, RP-18/2018) and followed the most recent version of the Declaration of Helsinki.

Between November 2013 and December 2016, 127 patients were implanted with METHA short stems in our institute for secondary arthritis of the hip joint. Out of these, 87 patients (107 hips) with age < 60 years, pre-operative diagnosis of an ONFH, minimum 36 months follow-up, and consent to participate were included in the study. The desired data were collected from institutional arthroplasty register, and patients were invited for a clinical and radiological examination at the latest follow-up. The cohort included 52 men and 35 women. There were 20 patients (23%) with bilateral THA and 67 patients (77%) with unilateral THA. The mean age of patients was 43.7 years (range, 27–60 years; standard deviation [SD], 9.2 years). The mean body mass index (BMI) of the study population was 24.9 (SD, 3.1) with 41% patients being overweight (BMI, 25–29.9 kg/m<sup>2</sup>) and 3% patients

obese (BMI > 30 kg/m<sup>2</sup>). Twenty-nine patients (33.3%) had steroid-induced ONFH, 11 patients (12.6%) had an alcohol-induced ONFH, 19 patients (21.8%) had an idiopathic cause, and 27 patients (31%) had traumatic ONFH while 1 patient had ONFH secondary to chronic renal failure (CRF). The causes with underlying grossly abnormal metabolic changes<sup>13-15)</sup> leading to marked osteoporosis and poor remodeling potential, viz., alcohol-, glucocorticoids-, and CRF-induced ONFH, were included in group I, which had 41 patients (47.12%). Group II included idiopathic and traumatic causes of ONFH and had 46 patients (52.88%). Traumatic ONFH was secondary to the neck of femur fracture and posterior dislocation of the hip in 18 patients (20.7%) and 9 patients (10.3%), respectively.

All patients received mono block partial neck-retaining cementless METHA stem. The cases were operated by the senior surgeon (RM) using the posterior approach to the hip. In hips with posttraumatic ONFH, a bone burr was used to create a legit track for femur prostheses by removing sclerotic bone in the neck region and/or neocortex around the implant in the metaphyseal area. Eight hips had cannulated cancellous screws *in situ*, and 1 hip had a dynamic hip screw with a side plate *in situ* for the neck of femur fracture fixation in the index surgery. The implant was removed after a hip dislocation to facilitate easy removal of the femoral head from the acetabulum. In a hip with dynamic hip screw, the side plate was cut below the shoulder region with a metal-cutting high-speed burr to remove the plate barrel and lag screw. The side plate was retained to avoid stress risers created by empty screw tracks.

The criteria for prophylactic wiring of the calcar region with a monofilament stainless steel wire before placement of METHA stem was hips with a history of core decompression or osteosynthesis, leading to sclerosis or neocortex formation in the femoral neck with poor corticomedullary differentiation, a large metaphyseal and/or femoral neck cyst with sclerotic margins, and hips with grossly thin bony cortices of the femoral neck.

The intraoperative femoral fracture was defined as any break in the continuity of bone in the proximal femur that happened during preparation or implantation of the femoral prostheses. The low-grade fracture was defined as a linear unicortical nondisplaced fracture line above the lesser trochanter, and the high-grade fracture was defined as a unicortical nondisplaced fracture line extending below the lesser trochanter. All intraoperative femoral fractures with stable femoral prostheses were managed with cerclage of the proximal femur with monofilament stainless steel wires. The patients were allowed to walk with

assistance on the day of surgery. They followed a standard physiotherapy protocol till discharge. Weight-bearing was delayed for 6 weeks in hips with cerclage wiring.

At the latest follow-up, the clinical evaluation included documentation of symptoms and signs related to operated hips and functional assessment using Harris Hip Score (HHS). Radiological evaluation was done on anteroposterior and lateral radiographs of the operated hip, which were evaluated for component positioning, osteointegration, subsidence, aseptic loosening, and infection. Femoral component fixation (osteointegration) was assessed by observing bone ingrowth and trabeculae development in Gruen's zones around the prostheses as described by Engh et al.<sup>16)</sup> Stem subsidence/loosening was defined as femoral component axial sinking > 2 mm or a varus/valgus shift of more than 3°.<sup>17)</sup>

### Statistical Analysis

The data were entered in Excel and analyzed using Stata ver. 15.2 (Stata Corp., College Station, TX, USA). Mean (SD) and frequency (percentage) were calculated as appropriate. Paired *t*-test was used to compare HHS at various follow-up assessments with the baseline scores, as well as with previous visit scores. HHS was compared across patients with group I and group II causes and across sex using *t*-test. Association with risk factors for cerclage (none, prophylactic, and intraoperative fracture) during THA were assessed using analysis of variance (ANOVA) and Fisher's exact test, followed by post-hoc comparisons using Scheffe test (after ANOVA) and using logistic regression with post-estimation pairwise comparisons of marginal linear predictions (after Fishers exact test). A *p* < 0.05 was considered statistically significant.

## RESULTS

The average follow-up of patients was 47.2 months (range, 36–70 months; SD, 7.9). The function improved from a mean preoperative HHS of 58.22 (SD, 4.48) to 95.93 (SD, 2.25) at the final follow-up. No significant difference was found in HHS of patients with atraumatic ONFH (mean, 94.4; SD, 1.7) and traumatic ONFH (mean, 94.7; SD, 1.7) at final follow-up (*p* = 0.67).

The femur was classified as per Dorr type on preoperative radiographs: type A was observed in 79.3% hips and type B was in 20.7% hips. No hip was Dorr type C. The mean postoperative leg length discrepancy was 0.8 mm (range, 0–4; SD, 1.3 mm). No patient had more than 10 mm limb length difference in the postoperative period. The femoral prosthesis alignment was also observed in

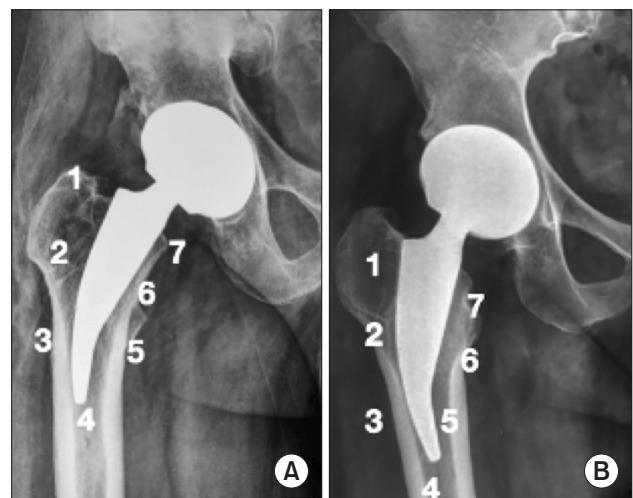
postoperative radiographs: 4 patients (4.6%) had valgus placement of the prosthesis, and all were operated for posttraumatic ONFH. At the latest follow-up, all femoral prostheses showed signs of osteointegration with the host bone (Fig. 1). There was no radiographic evidence of stem subsidence or migration. Also, no dislocation or surgical site infection was observed during the study period.

### Risk of Cerclage Wiring and Associated Factors

Sixteen patients received cerclage wiring during surgery: 9 patients had an intraoperative fracture whereas 7 patients received prophylactic cerclage wiring for poor bone stock. After analyzing demographic factors, etiology and surgical factors, both prophylactic cerclage wiring and intraoperative fracture were found to be associated with group I, i.e., ONFH secondary to alcohol, steroids and renal disorders (*p* = 0.002) (Table 1). No association was found with sex (*p* = 0.647), femoral prostheses size (*p* = 0.272), presence of implant in posttraumatic ONFH (*p* = 0.359), single sitting bilateral THA (*p* = 0.890), Dorr type (*p* = 0.775), and stem alignment (*p* = 0.082). On post-hoc analysis, BMI was also not found to be associated with prophylactic cerclage wiring (*p* = 0.842) and intraoperative fracture risk (*p* = 0.612).

In the hips with intraoperative fractures, 8 had low-grade femoral split and 1 had a high-grade femoral split of the calcar region. All patients were managed by cerclage wiring of the calcar region only.

The prophylactic cerclage wiring of the proximal femur was done before the beginning of femoral canal preparation to prevent an intraoperative split/fracture. No



**Fig. 1.** (A, B) Radiographs showing signs of osteointegration mainly in Gruen zones 2, 6, and 7. Bone remodeling and trabeculae formation could be observed in the metaphyseal region.

**Table 1.** Risk Factors of Cerclage Wiring of the Femur During Short-Stem Total Hip Arthroplasty

Variable	Reason for cerclage				p-value
	No	Prophylactic	Intraoperative fracture	Total	
Sex					0.648*
Female	27 (38)	3 (42.9)	5 (55.6)	35 (40.2)	
Male	44 (62)	4 (57.1)	4 (44.4)	52 (59.8)	
BMI (kg/m <sup>2</sup> )	25.0 ± 3.1 (n = 71)	22.3 ± 3.4 (n = 7)	26.1 ± 2.7 (n = 9)	24.9 ± 3.1 (n = 87)	0.040 <sup>†</sup>
BMI					0.497*
Normal	33 (46.5)	4 (57.1)	4 (44.4)	41 (47.1)	
Underweight	1 (1.4)	1 (14.3)	0	2 (2.3)	
Overweight	34 (47.9)	2 (28.6)	5 (55.6)	41 (47.1)	
Obese	3 (4.2)	0	0	3 (3.4)	
Etiology					0.127*
Atraumatic	46 (64.8)	7 (100)	7 (77.8)	60 (69)	
Traumatic	25 (35.2)	0	2 (22.2)	27 (31)	
Etiology					0.002*
Group I	28 (39.4)	7 (100)	6 (66.7)	41 (47.1)	
Group II	43 (60.6)	0	3 (33.3)	46 (52.9)	
Bilateral operated					0.890*
No	55 (77.5)	5 (71.4)	7 (77.8)	67 (77)	
Yes	16 (22.5)	2 (28.6)	2 (22.2)	20 (23)	
Previous surgery implant					0.360*
No	64 (90.1)	7 (100)	7 (77.8)	78 (89.7)	
Yes	7 (9.9)	0	2 (22.2)	9 (10.3)	
Dorr type					0.775*
Group I	57 (80.3)	5 (71.4)	7 (77.8)	69 (79.3)	
Group II	14 (19.7)	2 (28.6)	2 (22.2)	18 (20.7)	
Short stem size	1.5 ± 1.5 (n = 71)	2.4 ± 1.5 (n = 7)	1.7 ± 1.6 (n = 9)	1.6 ± 1.5 (n = 87)	0.272 <sup>†</sup>
Stem alignment					0.082*
Neutral	69 (97.2)	7 (100)	7 (77.8)	83 (95.4)	
Valgus	2 (2.8)	0	2 (22.2)	4 (4.6)	

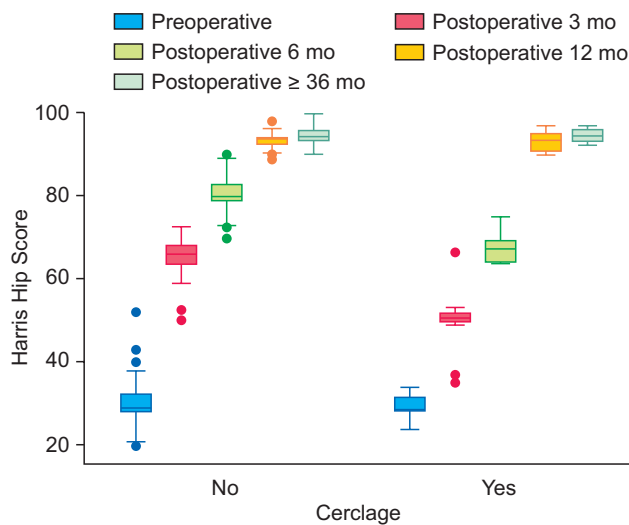
Values are presented as number (%) or mean ± standard deviation.

BMI: body mass index, Group I: alcohol, glucocorticoids, and renal disorder-induced osteonecrosis, Group II: idiopathic and traumatic osteonecrosis.

\*Fisher's exact test. <sup>†</sup>Analysis of variance.

difference was found in the functional outcome (HHS) of patients with or without cerclage wiring (Fig. 2). No patient was revised for subsidence, aseptic loosening, infec-

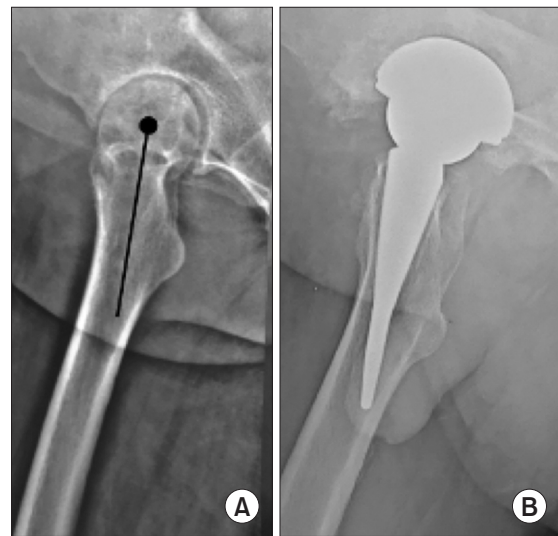
tion, or implant breakage till the latest follow-up.



**Fig. 2.** Functional outcome assessed using Harris Hip Score. Similar trends of improvement were observed in patients with and without cerclage wiring of the proximal femur.

## DISCUSSION

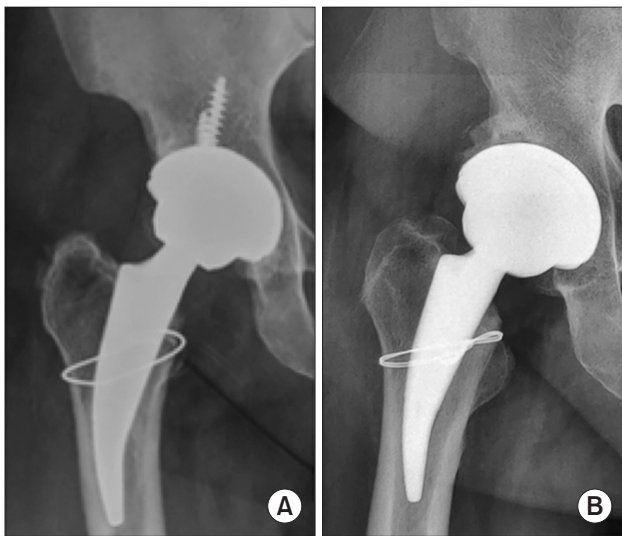
Hip arthritis secondary to ONFH is a common indication for THA.<sup>6</sup> It usually affects patients in the third to fifth decade of life.<sup>2,4</sup> In young patients, an ideal THA should preserve bone stock for inevitable future revision surgery.<sup>4</sup> This led to the development of bone-preserving, short-stem arthroplasty. Short stems are less than 12 cm in length and bone-preserving because of the more proximal anchor compared to that of standard length stems.<sup>5</sup> They are classified into neck-containing designs (CUT stem, ESKA Implants, Lubeck, Germany), partial neck-containing designs (METHA stem, BBraun, Aesculap, Tuttlingen, Germany; NANOS stem, Smith and Nephew, Marl, Germany), and neck resection designs (shortened standard stems with diaphyseal anchorage, e.g., TriLock stem, DePuy Synthes).<sup>4</sup> METHA stem follows the partially retained neck to restore the anatomical hip center and anchors primarily in the metaphyseal region (Fig. 3).<sup>4</sup> However, the philosophy and design of this type of stem have been questioned in patients with ONFH.<sup>6</sup> There is histological evidence that ONFH not only involves the intracapsular region but may also extend into the neck and metaphyseal region.<sup>9,10</sup> So, placing the implant within or close to the pathological bone may lead to faulty osteointegration and early aseptic loosening.<sup>9,12</sup> These concerns were confirmed to be unfounded in the present study, and we observed satisfying signs of osteointegration around the stem in zones described by Gruen. A possible explanation to good primary fixation and osteointegration is



**Fig. 3.** Anatomical restoration of the hip center with METHA short-stem arthroplasty. (A) The long axis of neck meeting the center of femoral head. (B) Short stem following femoral neck to restore the hip center.

the biconical implant design and anatomical restoration of the hip, leading to circumferential and physiological loading of the proximal femur.<sup>4,6</sup> Studies have also shown excellent results of METHA stem in terms of osteointegration.<sup>2,4,6,12</sup> However, in the present study, cerclage wiring during THA was required for intraoperative fractures and poor bone quality in a significant number of patients. Several researchers have documented gross quantitative and qualitative deterioration of bone in the proximal femur due to osteonecrosis.<sup>9,10,14,15</sup> Gruner and Heller<sup>18</sup> in their article on patient selection for short stems advocated intraoperative assessment of the bone quality of the femoral ring after neck osteotomy to determine the indication for the use of a short stem. Many surgeons have proposed weak structural bone as a contraindication for primarily calcar loading short stems.<sup>4,18,19</sup> In the present study, the bone defect was found more profound in ONFH secondary to steroids, alcohol and renal pathologies, and patients received the METHA stem irrespective of bone quality. Cerclage wiring of the calcar region was done to augment support to the implant during initial stages of osteointegration (Fig. 4). Use of cables and wires is a common and well-documented method for intraoperative fracture management during THA.<sup>20</sup> But there are only biomechanical and cadaveric studies investigating the role of prophylactic wiring during primary THA. Nwankwo et al.<sup>21</sup> in their biomechanical study showed that the prophylactic cerclage of the proximal femur increases hoop resistance, decreases strain across bone during femoral broaching of THA, and

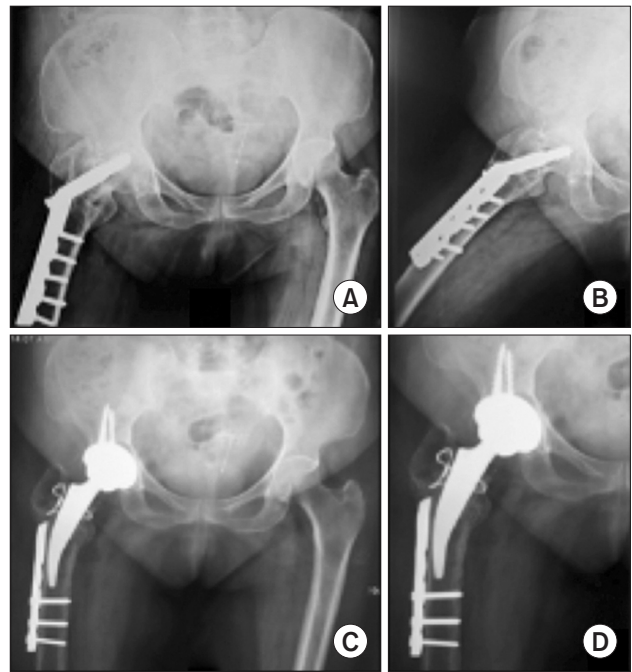




**Fig. 4.** Cerclage wiring of the proximal femur. (A, B) Prophylactic wiring of the proximal femur to prevent an intraoperative fracture due to poor bone quality. Signs of osteointegration could be observed around the femoral prosthesis.

plays a clinical role to reduce intraoperative fractures. Similarly, Herzworm et al.<sup>22)</sup> and Waligora et al.<sup>23)</sup> in their cadaveric studies found prophylactic wiring increases not only hoop stress resistance to reduce intraoperative fractures during THA but also rotation and energy to failure in well-fixed press-fit femoral implants to minimize the risk of early periprosthetic fracture. Good radiological and functional outcomes in the present study advocate the use of prophylactic cerclage wiring in hips with poor bone stock as a viable option to offer bone-preserving benefits of short stems in young adults.

Posttraumatic AVN poses a surgical challenge in THA due to the presence of implants used in the index surgery. Cannulated cancellous screws and dynamic hip screws with the plate are commonly used implants for the neck of femur fractures in adults. Screw tracks with surrounding sclerotic bone increase chances of *via falsa* placement of short stems.<sup>19)</sup> In the present study, we found assiduous use of a high-speed burr useful in the sclerotic bone area of the metaphyseal region to create a legit track for a prosthesis. Also, the use of short stems in posttraumatic osteonecrosis allowed us to retain implants present in the diaphyseal region and prevent the necessity of longer prostheses to bypass the implant region to avoid stress risers (Fig. 5). Limitations of the present study are the small cohort size and the retrospective study design. The study may be underpowered to find the association in cerclage wiring during THA with other demographic and surgical factors of patients.



**Fig. 5.** Short-stem arthroplasty in posttraumatic arthritis. (A, B) Preoperative radiographs showing right hip arthritis with an implant *in situ*. (C, D) Side plate of a dynamic hip screw cut below the shoulder region to remove lag screw. Proximal two screws were also removed to accommodate the short stem.

To conclude, METHA short-stem THA offered excellent functional and radiological outcomes in both atraumatic and traumatic ONFH. However, precaution must be exercised in patients with steroids-, alcohol-, and renal disorders-induced ON due to poor bone quality and higher chances of intraoperative fractures. Also, additional measures such as the use of a high-speed burr and prophylactic cerclage wiring in ONFH may allow predictable and safe use of short stems.

## CONFLICT OF INTEREST

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

## ORCID

Rajesh Malhotra <https://orcid.org/0000-0001-5971-003X>  
 Saurabh Gupta <https://orcid.org/0000-0002-5133-3572>  
 Vivek Gupta <https://orcid.org/0000-0002-6157-3705>  
 Vikrant Manhas <https://orcid.org/0000-0003-3025-5373>

## REFERENCES

- Shon WY, Park BY, R RN, Park PS, Im JT, Yun HH. Total hip arthroplasty: past, present, and future. What has been achieved? *Hip Pelvis*. 2019;31(4):179-89.
- Mersch D, Hane R, Tohidnezhad M, Pufe T, Drescher W. Bone-preserving total hip arthroplasty in avascular necrosis of the hip—a matched-pairs analysis. *Int Orthop*. 2018;42(7):1509-16.
- Kurtz SM, Lau E, Ong K, Zhao K, Kelly M, Bozic KJ. Future young patient demand for primary and revision joint replacement: national projections from 2010 to 2030. *Clin Orthop Relat Res*. 2009;467(10):2606-12.
- Floerkemeier T, Budde S, Gronewold J, et al. Short-stem hip arthroplasty in osteonecrosis of the femoral head. *Arch Orthop Trauma Surg*. 2015;135(5):715-22.
- Castelli CC, Rizzi L. Short stems in total hip replacement: current status and future. *Hip Int*. 2014;24 Suppl 10:S25-8.
- Floerkemeier T, Tscheuschner N, Calliess T, et al. Cementless short stem hip arthroplasty METHA as an encouraging option in adults with osteonecrosis of the femoral head. *Arch Orthop Trauma Surg*. 2012;132(8):1125-31.
- Chandler HP, Reineck FT, Wixson RL, McCarthy JC. Total hip replacement in patients younger than thirty years old: a five-year follow-up study. *J Bone Joint Surg Am*. 1981;63(9):1426-34.
- Cornell CN, Salvati EA, Pellicci PM. Long-term follow-up of total hip replacement in patients with osteonecrosis. *Orthop Clin North Am*. 1985;16(4):757-69.
- Tingart M, Beckmann J, Opolka A, et al. Analysis of bone matrix composition and trabecular microarchitecture of the femoral metaphysis in patients with osteonecrosis of the femoral head. *J Orthop Res*. 2009;27(9):1175-81.
- Calder JD, Pearse MF, Revell PA. The extent of osteocyte death in the proximal femur of patients with osteonecrosis of the femoral head. *J Bone Joint Surg Br*. 2001;83(3):419-22.
- Johansson HR, Zywił MG, Marker DR, Jones LC, McGrath MS, Mont MA. Osteonecrosis is not a predictor of poor outcomes in primary total hip arthroplasty: a systematic literature review. *Int Orthop*. 2011;35(4):465-73.
- Suksathien Y, Sueajui J. Mid-term results of short stem total hip arthroplasty in patients with osteonecrosis of the femoral head. *Hip Int*. 2019;29(6):603-8.
- Waewsawangwong W, Ruchiwit P, Huddleston JI, Goodman SB. Hip arthroplasty for treatment of advanced osteonecrosis: comprehensive review of implant options, outcomes and complications. *Orthop Res Rev*. 2016;8:13-29.
- Seamon J, Keller T, Saleh J, Cui Q. The pathogenesis of non-traumatic osteonecrosis. *Arthritis*. 2012;2012:601763.
- Tsai SW, Wu PK, Chen CF, et al. Etiologies and outcome of osteonecrosis of the femoral head: etiology and outcome study in a Taiwan population. *J Chin Med Assoc*. 2016;79(1):39-45.
- Engh CA, Massin P, Suthers KE. Roentgenographic assessment of the biologic fixation of porous-surfaced femoral components. *Clin Orthop Relat Res*. 1990;(257):107-28.
- Kim YH, Kim VE. Uncemented porous-coated anatomic total hip replacement: results at six years in a consecutive series. *J Bone Joint Surg Br*. 1993;75(1):6-13.
- Gruner A, Heller KD. Patient selection for shorter femoral stems. *Orthopedics*. 2015;38(3 Suppl):S27-32.
- von Lewinski G, Floerkemeier T. 10-year experience with short stem total hip arthroplasty. *Orthopedics*. 2015;38(3 Suppl):S51-6.
- Berend KR, Lombardi AV Jr, Mallory TH, Chonko DJ, Dodds KL, Adams JB. Cerclage wires or cables for the management of intraoperative fracture associated with a cementless, tapered femoral prosthesis: results at 2 to 16 years. *J Arthroplasty*. 2004;19(7 Suppl 2):17-21.
- Nwankwo CD, Parrish R, Leasure J, McGann WA. Prophylactic cerclage with braided polyblend suture during femoral broaching. *Orthopedics*. 2016;39(6):e1183-7.
- Herzwurm PJ, Walsh J, Pettine KA, Ebert FR. Prophylactic cerclage: a method of preventing femur fracture in uncemented total hip arthroplasty. *Orthopedics*. 1992;15(2):143-6.
- Waligora AC 4th, Owen JR, Wayne JS, Hess SR, Golladay GJ, Jiranek WA. The effect of prophylactic cerclage wires in primary total hip arthroplasty: a biomechanical study. *J Arthroplasty*. 2017;32(6):2023-7.