Modified Pauwels' Intertrochanteric Osteotomy in Neglected Femoral Neck Fracture

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Received: 26 March 2008 / Accepted: 19 December 2008 / Published online: 14 January 2009
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Abstract Many reported treatment methods for neglected femoral neck fractures do not always satisfactorily address nonunion, coxa vara, and limb shortening. We retrospectively reviewed the functional outcome of the modified Pauwels' intertrochanteric osteotomy in 48 adults (mean age, 48.1 years) to determine whether this approach would correct those problems. The average preoperative limb shortening was 2.7 cm (range, 1.5–5 cm) in 38 patients and mean neck-shaft angle was 107.3° (range, 80°–120°). The minimum followup was 2 years (mean, 6.1 years; range, 2–16.5 years). Union was achieved in 44 of the 48 patients. Union also was achieved in two of the four nonunions after revision osteotomy. Postoperative avascular necrosis of the femoral head developed in two of the 48 patients after an average followup of 6 years. Limb-length equalization was achieved in 40 (83%) patients and 40 had near-normal gait. The average neck-shaft angle at the final followup was 132.7° (range, 120°–155°). The average Harris hip score was 86.7 points and Merle d'Aubigné-Postel score was 14.1. We believe the primary modified Pauwels' intertrochanteric osteotomy is a reliable alternative to achieve

fracture healing in neglected femoral neck fractures and simultaneously correct associated coxa vara and shortening. A two-stage surgical incision makes the procedure simple and less demanding.

Level of Evidence: Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

In developing countries, it is not uncommon to see patients with femoral neck fractures after a delay of several months because of poverty, lack of facilities, ignorance, and faith in traditional healers [8, 9, 15, 25, 28, 29]. Prosthetic replacement generally is the preferred treatment for patients older than 60 years [10, 13, 21], and salvage of the femoral head has been advocated for younger patients [10, 14, 21, 27]. With increasing life expectancy of patients with prostheses, late complications of prosthetic replacement are increasing [6, 21].

Numerous procedures have been described for salvaging the femoral head to avoid or delay hip replacement in patients younger than 60 years. In one study, revision fixation alone for nonunion of femoral neck fractures achieved 100% union in selected patients who presented without avascular necrosis (AVN) of the femoral head and limb shortening less than 1.5 cm [32]. One study reported muscle pedicle bone grafts had a 75% failure rate in neglected fractures when performed more than 90 days after injury [22]. Free fibular bone grafting reportedly provided satisfactory results in 88% of patients [25]; however, coxa vara in 28%, mean leg-length discrepancy of 2.9 cm, donor-site morbidity, and application of hip spica casts are drawbacks of the procedure. In another

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Each author certifies that his or her institution has approved the reporting of these cases, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Table 1. Interobserver variability with Kappa values

Observers	Pauwels classification		Classification by Sandhu et al. [29]		Union at osteotomy site		Union at fracture site	
	Kappa	95% CI	Weighted Kappa	95% CI	Kappa	95% CI	Kappa	95% CI
1 & 2	0.600	0.364 to 0.836	0.328	0.068 to 0.566	0.413	0.250 to 0.576	0.308	0.149 to 0.467
2 & 3	0.368	0.059 to 0.678	0.242	−0.005 to 0.499	0.292	0.114 to 0.470	0.091	−0.091 to 0.273
1 & 3	0.077	−0.219 to 0.373	0.371	0.155 to 0.638	0.247	0.063 to 0.431	0.310	0.146 to 0.473
Mean	0.348		0.314		0.317		0.236	

CI—Confidence interval.

study, internal fixation and fibular bone grafting had a failure rate of 67% in patients with neglected femoral neck fractures presenting with either a proximal fragment smaller than 2.5 cm or with a fracture gap 2.5 cm or greater, or having AVN of the femoral head [29]. Furthermore, open reduction is likely to interfere in an already precarious blood supply of the head of the femur [29]. Vascularized fibular grafting [3, 14] reportedly has achieved 100% union; however, vascularized fibular grafting with or without osteotomy is time-consuming, requires a high degree of technical skill, and is beyond the competence of the typical orthopaedic surgeon [29]. Valgus osteotomy with or without bone grafting and THA have been widely accepted as the only two viable options for treatment of femoral neck nonunion [10, 11, 16, 20, 21, 24, 27, 30]. Some studies highlighted the usefulness of valgus intertrochanteric osteotomy for management of nonunions; however, the literature is scant regarding its role in neglected femoral neck fractures [2, 16, 20, 30].

In light of complications associated with other methods for treatment of neglected femoral neck fractures, we attempted to answer three questions in our retrospective cohort study: (1) What is the role of the modified Pauwels' intertrochanteric osteotomy in neglected femoral neck

fractures in adults regarding union and functional outcome? (2) Can an osteotomy correct the nonunion, limb-length discrepancy, coxa vara, and avoid AVN of the femoral head, associated with other methods of treatment? (3) Are our results using the osteotomy comparable with published results?

Materials and Methods

We retrospectively reviewed all 55 patients with femoral neck fractures neglected for more than 12 weeks and treated with Pauwels' intertrochanteric osteotomy, as modified by Mueller [23], between 1990 and 2004. We excluded seven patients who did not have a minimum followup of 2 years. That left 48 patients for the study; there were 21 men and 27 women with an average age of 48.1 years (range, 26–82 years; standard deviation [SD], 12.9 years). The average time between injury and surgery was 44 weeks (range, 12–208 weeks; SD, 57 weeks). The right hip was involved in 28 patients and the left in 20. Forty-three patients had fallen and five were injured in traffic accidents. The minimum followup was 2 years (mean, 6.1 years; range, 2–16.5 years).

Fig. 1A–C (A) An AP radiograph is shown of a patient before application of skeletal traction. The fracture gap is less than 1 cm and therefore is Type I according to the classification of Sandhu et al. [29]. (B) An AP radiograph is shown of the same patient after skeletal traction. There is a gradual increase in the size of the fracture gap. (C) This radiograph shows a Type III fracture gap according to the classification of Sandhu et al.

Preoperative radiographs were assessed for fracture classification by three blinded observers not associated with treatment. Fractures were classified as per classifications of Pauwels and Sandhu et al. [29]. A fracture was classified as

the type for which at least two observers agreed. According to Pauwels' classification, there were 12 Type II fractures and 36 Type III fractures (mean kappa value, 0.348) (Table 1); and according to the classification of Sandhu

Fig. 2A–D (A) A tracing is shown of a preoperative AP radiograph. (B) In this tracing, the Pauwels' angle is 45°. Lines AB = femoral shaft axis; AC = perpendicular to femoral axis; AD = fracture line intersecting the perpendicular to femoral shaft axis. The repositioning angle to place the fracture line at the right angle to the resultant R is therefore $45^\circ - 25^\circ = 20^\circ$. Lines EF and EG represent the proximal and distal limbs of the intertrochanteric osteotomy. A 20° intertrochanteric wedge (EFG) has been defined. A 15-mm breadth of bone is preserved for the elbow of the double-angled blade plate between H and EF to ensure stable osteosynthesis. The seating chisel has been inserted from the anatomic landmark marked H. The flap of the chisel

is kept parallel to the femoral shaft making an angle of 80° with the rest of the chisel (supplementary angle of 120° of the blade plate, ie, $60^\circ +$ reposition angle, ie, $20^\circ = 80^\circ$). The chisel is advanced into the inferior half of the femoral neck for a length equal to that of the blade length of the 120° contoured osteotomy plate. This is 85 mm in this illustration. (C) An intertrochanteric wedge of bone has been excised as per preoperative planning and the chisel has been replaced with an 85-mm blade length of a 120° double-angled osteotomy plate. (D) After excision of the intertrochanteric wedge, the distal fragment is abducted and the plate is stabilized with screws. The excised wedge of bone is placed in the elbow of the implant shown by an arrow.

et al., there were 34 Type I fractures, 10 Type II fractures, and four Type III fractures (mean kappa value, 0.314) (Table 1). The average preoperative limb shortening was 2.7 cm (range, 1.5–5 cm; SD, 0.9 cm) in 38 patients. Preoperative upper tibial skeletal traction was used for 2 to 3 weeks with weights up to 10 to 12 kg to bring the shaft of the femur as distal as possible in patients with limb shortening. In all patients with limb shortening, the fracture gap was reassessed after skeletal traction using the classification of Sandhu et al. [29]. The size of the fracture gap varied after skeletal traction in four patients (Fig. 1). An

independent nontreating observer (SM) identified AVN of the femoral head primarily on plain radiographs using the radiographic criteria of Ficat and Arlet as reported by Dabov and Perez [4]. One patient had Stage 2A AVN of the femoral head seen on preoperative radiographs using these criteria. The preoperative mean neck-shaft angle was 107.3° (range, 80° – 120° ; SD, 11.2°). Preoperative planning was performed to calculate Pauwels' angle and define the steps of surgery for type and size of implant and point of entry on the trochanter for seating the blade tip in the inferior and posterior quadrants of the femoral head (Fig. 2).

Fig. 3A–B (A) An intraoperative photograph of the modified Pauwels' intertrochanteric osteotomy shows the initial 5-cm longitudinal incision and insertion of the AO chisel into the neck of the femur after stabilization of the fracture with a 6.5-mm cancellous lag screw. (B) An intraoperative photograph shows extension of the incision (second

stage) to perform the osteotomy and osteosynthesis with the double-angled osteotomy blade plate. The vastus lateralis muscle has been divided and the anterior $\frac{2}{3}$ of the muscle belly has been lifted anteriorly to define the site of the intertrochanteric osteotomy.

Fig. 4A–B (A) An AP radiograph of a 53-year-old woman shows a Pauwels' Type III neglected nonunion of 2 years duration. The femoral neck is completely absorbed. Proximal migration of the distal fragment resulted in 5-cm shortening of the limb. The lesser trochanter abutting the head of the femur can be seen. (B) An AP radiograph of the pelvis, including both hips taken 2 years after a modified Pauwels' intertrochanteric osteotomy and internal fixation,

shows sound union of the fracture and the osteotomy site. The distal fragment was lateralized and the excised intertrochanteric wedge of bone was placed in the elbow of the double-angled blade plate as bone graft. The consolidation of the intertrochanteric wedge of bone is denoted by an arrow. The gain in limb length is evident by the distal migration of the lesser trochanter away from the femoral head. The pelvic tilt of 1.5 cm compensates for the residual shortening.

We used the Watson-Jones approach [31] with the patient on a conventional operative table in the supine position, and with image intensifier control. Surgery was performed through a two-stage incision. A 5-cm longitudinal incision beginning at the tip of the greater trochanter was made initially followed by later extension of that incision. Manual traction was applied to the affected limb through the skeletal tibial pin to correct shortening and achieve reduction under an image intensifier. The nonunion was provisionally stabilized using two 2.5-mm Kirschner wires to maintain the reduction. An appropriate 6.5-mm cancellous screw was used in the superior part of the neck to achieve interfragmentary compression of the nonunion. The Kirschner wires were removed after achieving interfragmentary compression. A seating chisel was introduced from the predetermined point of entry on the trochanter into the inferior and posterior quadrants of the head of the femur to make a track for the blade part of the double-angled osteotomy blade plate (Fig. 3A). Therefore, the major part of the procedure was performed through an initial 5-cm incision. Subsequently, the skin incision was extended to perform an intertrochanteric osteotomy (Fig. 3B) and to complete the procedure as described by Mueller [23]. Lateralization of the distal fragment was performed in patients with shortening greater than 4 cm, and the intertrochanteric wedge of bone was placed in the elbow of the double-angled blade plate to gain neck length (Fig. 4). We used no other treatment such as capsulotomy, excision of fibrous tissue, or bone grafting. Revision

osteotomy was performed for patients with persistent nonunion using the same procedure.

Patients were taught and encouraged to do pain-free intermittent quadriceps, hip, and knee flexion exercises starting on the second postoperative day with no supervision. They were advised not to lift the leg straight with an extended knee for 6 weeks. Partial weightbearing was permitted 6 weeks after surgery and full weightbearing was encouraged after 12 weeks.

Patients were followed at 6, 12, 24, 52, and 100 weeks and then once a year until last followup. Functional outcomes were assessed using the Harris hip score [7] and Merle d'Aubigné-Postel score [5]. An independent nontreating observer (SM) measured collapse at the fracture site from the articular cartilage to the tip of the blade on anteroposterior radiographs. Evaluation of the radiographs was performed by three blinded observers (SM, AG, AB) not involved in the treatment. Fractures were classified as united or not united if at least two of the three observers agreed. Union was defined as bridging of three of the four cortices and disappearance of fracture line on the plain radiographs for a patient who was able to bear full weight. Nonunion was defined as a fracture that did not heal within a year.

Results

Fracture union was achieved by 44 patients (Figs. 4, 5). Nonunion at the fracture site persisted in four patients

Fig. 5A–B (A) An AP radiograph of a 31-year-old man shows Type III (Sandhu et al.) neglected nonunion of 28 months duration. The femoral neck is completely absorbed. (B) An AP radiograph taken at the 16-year followup shows bridging of the fracture gap with a well-consolidated, newly formed femoral neck. The femoral head is viable and mild sclerosis of the weightbearing dome of the acetabulum is visible.

Table 2. Details of patients with nonunions

Patient number	Age (years)	Gender	Mean delay (weeks)	Sandhu et al. classification	Average neck-shaft angle (°)		Revision surgery	Outcome	Average Harris hip score	Average Merle d'Aubigné-Postel score	Average followup (years)
					Preoperative	Postoperative					
1	40	Male	13	I	110	135	Osteotomy	Fracture united	80	13	10.5
2	67	Female	12	I	110	138	Osteotomy	Fracture united	78	13	3
3	37	Male	156	III	100	140	Osteotomy	Fragmentation of femoral head and THA	75	12	10
4	36	Male	156	II	90	125	None	Limp	70	10	9

(Table 2). In two of these four patients, nonunion was observed owing to penetration of the blade into the joint preventing further collapse at the fracture site or loss of fixation (Fig. 6). In the other two patients, the osteotomy was not in adequate valgus. Of the four nonunions, the fracture united after revision osteotomy in two patients. Revision osteotomy caused fragmentation of the femoral head in Stage 2A AVN (Fig. 7) in the third patient who underwent subsequent THA. The fourth patient refused revision surgery. Average operative time (from skin incision to skin closure) for the procedure was 58.6 minutes (range, 45–71 minutes; SD, 6.4 minutes).

Limb-length equalization was achieved in 30 of the 38 patients with preoperative shortening. The remaining eight patients had an average preoperative shortening of 4.2 cm. Lateralization of the distal fragment was performed and an average shortening of 1.9 cm (range, 1.5–2.5 cm; SD, 0.4 cm) was observed in these patients at the last followup. The average neck-shaft angle at the final followup was 132.7° (range, 120°–155°; SD, 7.4°). No patient had coxa vara.

The average Harris hip score was 86.7 points (range, 70–97 points; SD, 7.3 points). Eight patients had fair functional outcomes (Harris hip scores of 70–79). Forty patients had good to excellent functional outcomes (Harris hip scores of 80–100) and all were able to squat on their toes and in the crossed-leg position. The average Merle d'Aubigné-Postel score in 48 patients was 14.1 (range, 10–17 points; SD, 1.6 points). There was no Trendelenburg gait in patients with equal limb lengths and near-normal neck-shaft angles.

Two patients had AVN of the femoral head develop postoperatively and showed changes of osteoarthritis. Of the two, one had Stage 2A AVN but a near-normal pain-free hip even 10 years after the osteotomy (Fig. 8). The second patient had excessive valgus of the hip of 155° and had Stage 3 AVN with painful osteoarthritis of the hip develop 7 years after osteotomy. The patient underwent a second valgus osteotomy and was symptom-free for more than 4 years at last followup. Eight patients had an appreciable limp. An average collapse of 6 mm (range, 3–10 mm; SD, 2.5 mm) was observed in 16 patients. A screw migrated into the joint in one patient, resulting in a painful hip. One patient had partial cut-through of the implant 4 weeks after surgery and a hip spica cast was applied. However, the fracture united in this patient and the implant was removed after union.

Discussion

Numerous treatment methods for neglected femoral neck fractures have been described that address either

Fig. 6A–B (A) An AP radiograph of a 67-year-old woman shows loss of fixation and implant cut-through in a neglected femoral neck fracture of 3 months duration. (B) An AP radiograph taken 2 years after revision osteotomy shows sound union of the fracture and the osteotomy site.

Fig. 7 An AP radiograph of a 37-year-old man with Type III (Sandhu et al.) neglected fracture shows postoperative penetration of the blade of the implant into the joint resulting from collapse at the fracture site. Revision osteotomy caused fragmentation of the head of the femur. THA was performed subsequently.

biomechanical or biologic factors [1–3, 9, 14, 16, 20, 22, 25, 28–30, 32]. However, persistence of nonunion, AVN, coxa vara, limb-length discrepancy, and persistent limp make treatment of neglected femoral neck fractures a challenge [21, 25, 28]. Our aims were (1) to evaluate the role of the modified Pauwels' osteotomy in adult patients with neglected femoral neck fractures regarding union and functional outcome; (2) to determine whether the osteotomy could address complications, such as nonunion, limb-length discrepancy, coxa vara, and AVN of the femoral head, associated with other treatment methods, and (3) to compare our results using the osteotomy with published results.

The major limitation of our study is lack of availability of modern imaging techniques to assess preoperative and postoperative viability of the femoral head; however, an average followup of 6.1 years is enough to assess the viability. We have performed the surgical technique by using a two-stage incision, but we have not compared the

Fig. 8A–C (A) An AP radiograph of a 54-year-old woman shows Type III (Sandhu et al.) neglected nonunion of 1 year's duration. The pseudarthrosis is evident. The patient had shortening of 3 cm. (B) An AP radiograph taken 1 year after the modified Pauwels' intertrochanteric osteotomy and internal fixation show healing and consolidation

of the fracture gap. (C) An AP radiograph taken at the 10-year followup shows Stage 2A AVN changes in the head of the femur. Healing of the track of the blade after removal of the implant can be seen.

advantages of this method of surgical exposure with those of a conventional surgical incision. We could not reliably assess time to union. The kappa statistics for assessing union by three blinded reviewers on the final films ranged from 0.247 to 0.413 (Table 1); these likely would have been lower for early followup films where healing is more difficult to detect. However, we believe the fact that the fractures united is more important in this population than when they healed.

The rate of fracture union (92%) in our patients is comparable to rates of other treatment methods (Table 3). Union rates of 85% to 90% have been reported for the valgus osteotomy [11, 30], and 88% to 95% for open reduction and internal fixation with compression screws and free fibular grafts [25, 28, 29]. The McMurray osteotomy has been performed for ununited fractures [28]. Sandhu et al. reported a failure rate greater than 60% in Group III fractures [29]. In our series, union was achieved in three of the four Group III fractures, bridging the fracture gap with a newly formed femoral neck (Fig. 5). A union rate of 72% to 82% has been reported with muscle pedicle bone grafting [1, 22]. Three of the four fractures with greater than 90 days duration failed to unite [22]. Vascularized iliac bone grafting achieved 100% union [8].

Limb shortening of 1 to 3.4 cm (mean, 2.3 cm) has been reported in 91% of patients treated with free fibular grafting and osteosynthesis with two compression screws [28]. Similarly, shortening of 0.9 to 3.9 cm (mean, 2.9 cm) was reported by Nagi et al. [25]. Coxa vara (9%–28%) is another drawback of free fibular grafting and muscle pedicle grafting [1, 22, 25, 28]. Abduction osteotomy has been suggested for coxa vara and leg-length discrepancy at a later stage after fracture union [25]. Limb-length equalization was achieved in 83%, and coxa vara was not seen in any of our patients. Gain in limb length results from placement of the proximal femur into a more valgus position [21]. In patients with shortening greater than 4 cm, valgization should be combined with lateralization of the distal fragment [19]. In patients with excessive proximal migration of the trochanter and coxa vara, a valgus osteotomy moves the lesser trochanter distally and helps to achieve limb length and neck-shaft angle (Fig. 4B).

Functional outcome in our patients is comparable with reported outcomes (Table 3). Eighty-three percent of patients had near-normal gait and could squat on their toes and in the crossed-leg position, an essential component of their day-to-day sociocultural activities. Others have reported similar results [29, 30]. Limping, a disadvantage of osteotomy was observed in 17% of our patients. Mathews and Cabanela mentioned postoperative limp occurring in almost all of their patients [21]. They related the high rate of persistent limp to the mechanical changes of decreased offset and abductor lever arm caused by the

Table 3. Comparison of studies

Authors	Number of patients	Minimum period of neglect (average)	Method	Union (%)	AVN (%)	Mean Limb-length discrepancy (cm) (%)	Coxa vara (%)	Functional outcome
Meyers et al. [22]	24 untreated; 8 failed ORIF	1 month	ORIF + MPBG	72	0	NQ	NQ	NQ
Baksi [1]	56	3 (6.3) months	MPBG + Moore's or Hagie pins	82	4 (FHC)	1-2.5 (32)	27	Good results in all united fractures
Huang [9]	16	3 (9.6) months	CR/ORIF ± IBG ± osteotomy	100	25	NQ	NQ	81% good results
Hou et al. [8]	5	2 (26.8) months	ORIF + Knowles pins + VIBG	100	0	2 (20)	NQ	Excellent results
Nagi et al. [25]	40	1.5 (5.1) months	ORIF + cannulated screw + FFG	95	20	2.9	27	70% good results
Kalra and Anand [11]	20	1 (4.3) month	ORIF + valgus osteotomy	85	10	NQ	NQ	75% good results
Sandhu et al. [29]	168	3 (29) weeks	CRIF + cannulated screw + FFG	88	4	0.5-1.5 (11)	NQ	88% good results
Sringari et al. [30]	20	3 (9.8) weeks	CRIF + osteotomy	90	0	Lengthening (20)	NQ	90% good results
Roshan and Ram [28]	32	12 weeks	CR/ORIF + 2 cannulated screws + FFG	91	0	2.3 (91)	9	91% good
Current authors	48	12 (44) weeks	Valgus osteotomy	100	6	1.9 (17)	0	83% good results

Union rate after primary procedure and functional outcome as quoted in respective articles has been cited; AVN = avascular necrosis; ORIF = open reduction and internal fixation; MPBG = muscle pedicle bone graft; CR = closed reduction; IBG = iliac bone graft; VIBG = vascularized iliac bone graft; FFG = free fibular graft; CRIF = closed reduction and internal fixation; FHC = femoral head collapse; NQ = not quoted.

valgus osteotomy [21]. The causes of limping in our patients were residual shortening of 2.5 cm (two patients), postoperative neck-shaft angle greater than 145° (four patients), screw migration into the joint causing hip pain (one patient), and osteoarthritis of the hip (one patient). The incidence of preoperative AVN in neglected femoral neck fractures is 2.08% in our patients as compared with 0% to 20% in other series [8, 9, 25, 28]. Preoperative AVN (44%) is not a contraindication to osteotomy and it may lead to good results despite older age and AVN [20]. Two of our patients had AVN develop postoperatively and remained symptom-free for 7 to 10 years (Figs. 6, 7). A repeat osteotomy provided relief in one patient. Nikolopoulos et al. reported only a few patients with AVN after internal fixation had disabling symptoms and required surgery [26].

The fracture gap varies after traction in patients with neglected fractures (Fig. 1). Patients with Groups I and II fractures with proximal migration of the trochanter may have Group III fractures using the classification by Sandhu et al. [29]. This may be the reason for the lower incidence of Group III fractures in our series and the series by Sandhu et al. [29].

Osteotomy is a biologic procedure that has been described in various studies [17–20]. The surgical technique under an image intensifier is simple and can be completed in an average of 58.6 minutes. The image intensifier allows closed reduction and completion of the operative procedure through a smaller incision than the full-length incision described by Watson-Jones [31]. The major part of the surgical procedure until insertion of the AO seating chisel is performed through the initial 5-cm incision (Fig. 3A). The two-stage surgical incision, therefore, decreases blood loss, and also avoids unnecessary wound exposure for the major part of the operation. A 20° to 30° wedge is sufficient to place the head of femur into valgus and larger intertrochanteric wedges of bone based on Pauwels' angle are not required [18]. Bone graft donor-site morbidity associated with other procedures is avoided [3, 14, 25, 28]. A satisfactory outcome can still be achieved through a revision osteotomy or arthroplasty if the initial procedure fails [12, 20].

We believe the modified Pauwels' intertrochanteric osteotomy should be considered as a primary procedure for treatment of neglected femoral neck fractures. Coxa vara and shortening can be corrected simultaneously. Limb-length equalization can be achieved by valgus positioning and lateralization of the distal fragment. The two-stage surgical incision and use of an image intensifier make the procedure simple and less demanding.

Acknowledgments We thank Dr Sarita Magu, professor in the Department of Radiodiagnosis and Imaging, Dr Anil Gulia and Dr

Amit Batra senior residents in the department of Orthopaedics, Pt. B. D. S. PGIMS, Rohtak, India, for fracture classification and radiologic assessment of healing of the fracture and osteotomy site, collapse at the fracture site, and changes of AVN in the head of the femur.

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