Results of Internal Fixation of Pauwels Type-3 Vertical Femoral Neck Fractures

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Background: It has been postulated that femoral neck fractures with a more vertical fracture line (i.e., a high Pauwels angle) may experience more shear forces and therefore may be predisposed to nonunion or loss of fixation. Although there is controversy regarding which fixation method is ideal, we are aware of no large clinical series in which the treatment outcomes of these fractures were evaluated. The purpose of this multicenter study was to evaluate a large consecutive series of high shear angle (>70°) femoral neck fractures to learn more about the outcomes, complications, and performance of various internal fixation strategies.

Methods: Between January 1993 and January 2005, seventy-six Pauwels type-3 (Orthopaedic Trauma Association [OTA] type-31B2.3) femoral neck fractures were treated in seventy-five patients with a mean age of forty-two years. Fourteen patients were lost to follow-up. Sixty-two fractures in sixty-one patients were followed to union or revision surgery, with a mean duration of follow-up of twenty-four months. Thirty-seven fractures were treated with cannulated screws and twenty-five, with a fixed-angle device. The reduction quality, accuracy of implant placement, time to surgery, influence of capsular decompression, and rates of nonunion and osteonecrosis were evaluated.

Results: Fifty-nine (95%) of the fractures had good-to-excellent reduction, and three had a fair reduction. There was a nonunion of eight (14%) of the fifty-nine fractures with a good-to-excellent reduction and two of the three with a fair reduction. There was a septic nonunion of one fracture treated with a dynamic hip screw. There was an aseptic nonunion of seven (19%) of the thirty-seven fractures treated with screw fixation alone as compared with two (8%) of the twenty-five fractures treated with a fixed-angle device. Osteonecrosis occurred after treatment of seven (11%) of the sixty-two fractures.

Conclusions: Despite timely, excellent reduction and accurate implant placement in the vast majority of cases, the nonunion rate was 19% for fractures treated with cannulated screws alone and 8% for those treated with a fixed-angle device. Although these failure rates are not significantly different, we believe that this study documents the challenging nature of this fracture pattern and the ideal fixation device remains undefined.

Level of Evidence: Therapeutic Level III. See Instructions to Authors for a complete description of levels of evidence.

Femoral neck fractures in young patients typically result from high-energy trauma. Anatomic reduction and internal fixation with an emphasis on preservation of the blood supply to the femoral head is the treatment of choice for younger patients[1,2]. Rates of osteonecrosis and nonunion have been reported as ranging from 10% to 45% and from 10% to 30%, respectively. A recent study of patients between fifteen and fifty years old showed that the fracture displacement and the quality of the reduction were the two most important factors determining progression to osteonecrosis in young patients with a femoral neck fracture[3]. Most previous investigators did not subanalyze results on the basis of the fracture pattern, however.

Pauwels classified femoral neck fractures into three categories on the basis of their degree of verticality (Fig. 1)[4]. Although there has been some debate about the exact angles that define the categories, the theoretical principle behind this classification is that fractures with a more vertical orientation experience more shear than do more horizontal fractures, which

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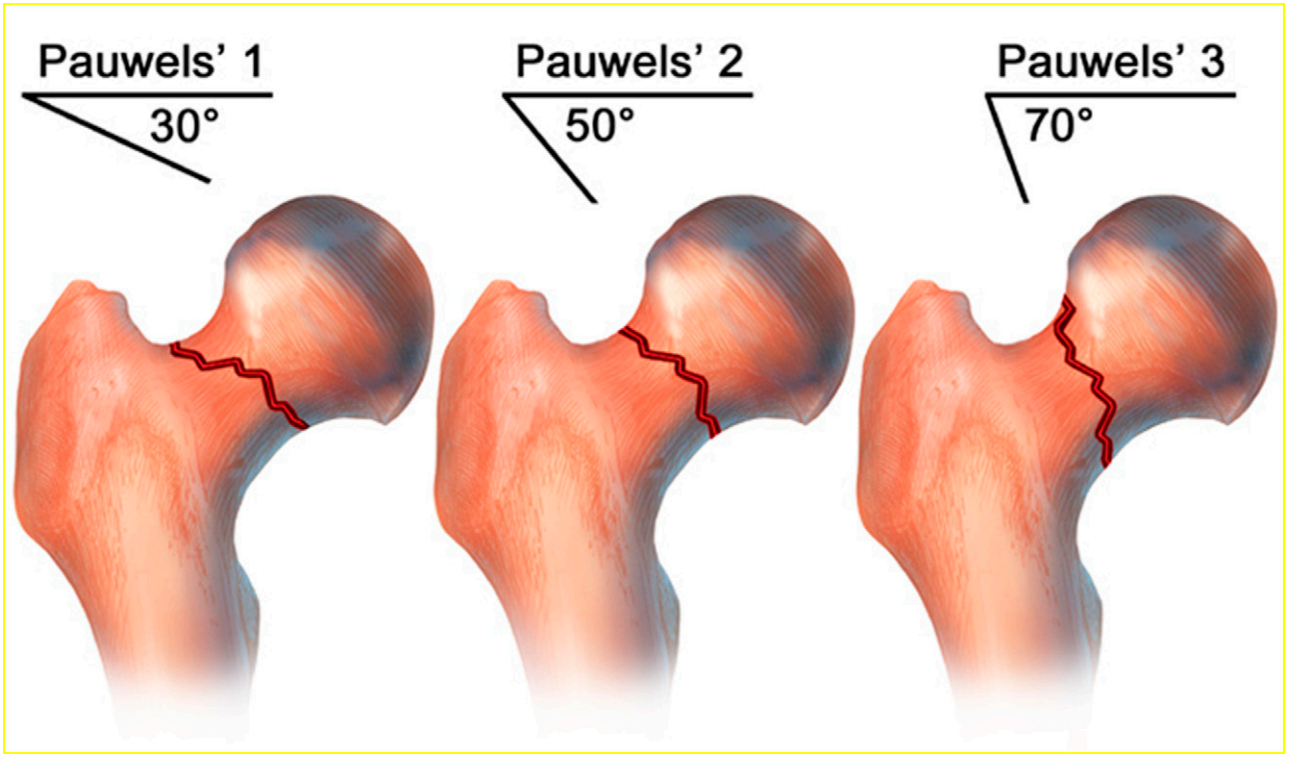

Fig. 1
Schematic representation of the Pauwels classification.

primarily experience compression with loading. Although some biomechanical and clinical studies support the concept that fractures with a higher "shear angle" are more unstable and therefore have a higher nonunion rate, to our knowledge there have been no large clinical series of high-shear-angle fractures to substantiate these claims or any prior studies analyzing the results of various fixation strategies—i.e., comparing screw fixation alone with a fixed-angle device.

The purpose of this study was therefore to evaluate a large consecutive series of Pauwels type-3 femoral neck fractures in order to learn more about the outcomes and complications associated with the treatment of these fractures as well as the performance of various internal fixation devices and strategies.

Materials and Methods

Between January 1993 and January 2005, seventy-six consecutive Pauwels type-3 femoral neck fractures in seventy-five skeletally mature patients were treated with internal fixation at three level-I trauma centers. Radiographs were reviewed and fracture verticality was measured with a goniometer according to the method of Pauwels[4]. Only transcervical fractures with ≥70° of verticality were included in the study. So-called basicervical fractures were excluded. To avoid confusion between basicervical and transcervical fractures, we chose to include only vertical fractures that had at least 1 cm of the superior part of the femoral neck between the fracture line and the medial aspect of the greater trochanter. If rotation of the lower limb precluded accurate measurement of the fracture verticality on the preoperative radiographs, intraoperative fluoroscopic images and immediate postoperative radiographs were used as well. We thought that the use of serial radiographs would allow us to confirm our suspicions of a vertical fracture noted on preoperative radiographs. Patients ranged in age from nineteen to sixty-four years, with a mean age of forty-two years. All fractures were classified as type-31B2.3 according to the system of the Orthopaedic Trauma Association (OTA)[5]. Fourteen patients were lost to follow-up. Therefore, sixty-two fractures in sixty-one patients were followed to union or revision surgery, with a mean duration of follow-up of twenty-four months (range, nineteen to thirty-six months).

After institutional review board approval for a retrospective review was obtained at each institution, clinical and radiographic data were retrospectively reviewed and results, complications, and the need for revision surgery were analyzed.

Eighteen patients had other orthopaedic injuries. When a patient had sustained multiple traumatic injuries, the life-threatening injuries were given priority for treatment and femoral neck fractures were treated urgently; however, all femoral neck fractures were treated within twenty-four hours after presentation. The choice of fixation device, the operative approach, and the need for capsulotomy were determined by the treating surgeon. All surgeons were fellowship-trained traumatologists.

Fifty-eight fractures were displaced, and four were nondisplaced. Thirty-seven fractures were treated with cannulated screw fixation alone (thirty-two were treated with parallel screws in a triangular configuration, and five were treated with

TABLE I Quality of Reduction According to the Type of Implant Used to Fix the Vertical Femoral Neck Fractures

	Reduction *(no. of fractures)*				
	Excellent	Good	Fair	Poor	Total
Cannulated screws	24	11	2	0	37
Dynamic hip screw	8	6	0	0	14
Cephalomedullary nail	4	5	0	0	9
Dynamic condylar screw	0	1	1	0	2

crossed-screw fixation), and twenty-five were treated with some form of fixed-angle device. We defined a fixed-angle device as an implant that maintains the angle of the femoral head fixation by virtue of femoral shaft fixation. Of those treated with a fixed-angle device, fourteen were treated with a dynamic hip screw (Synthes, Paoli, Pennsylvania); nine, with a cephalomedullary nail (Gamma; Stryker, Allendale, New Jersey); and two, with a dynamic condylar screw (Synthes) (Table I).

Eleven fractures were treated with a formal open reduction and internal fixation (with direct visualization of the fracture fragments), and fifty-one were treated with closed reduction and internal fixation. Generally, at our institutions, fractures were reduced under direct visualization if closed reduction was seen to be imperfect under fluoroscopic scrutiny in two planes. Fourteen of the fifty-eight displaced fractures were treated with a capsulotomy.

Since there is no standardized classification for assessing the quality of femoral neck reduction, the method of Haidukewych et al. was used[3]. On the basis of the degree of residual angulation and the amount of displacement, fracture reduction was classified as excellent (<2 mm of displacement and <5° of angulation in any plane), good (2 to 5 mm of displacement and/or 5° to 10° of angulation), fair (>5 to 10 mm of displacement and/or >10° to 20° of angulation), or poor (>10 mm of displacement and/or >20 ° of angulation, or any varus)[1,3,6,7]. Osteonecrosis was classified radiographically with use of the method of Ficat[8].

Results

Forty-six (74%) of the sixty-two fractures healed after the index operation without evidence of osteonecrosis at the time of final follow-up. One patient had to return to the operating room for repositioning of an intra-articular screw two days postoperatively, but the fracture went on to uneventful union at three months. Osteonecrosis occurred after treatment of seven (11%) of the sixty-two fractures, and there was a nonunion of ten (16%) of the sixty-two fractures. One patient had both of these complications. One of the seven nonunions was a septic nonunion that developed in a patient treated with a dynamic hip screw.

Subanalysis of the group that did not have septic failure demonstrated a mechanical failure (nonunion) rate of seven (19%) of thirty-seven fractures treated with screw fixation alone and two (8%) of twenty-five treated with a fixed-angle device ($p = 0.29$, Fisher exact test). Three of the five crossed cannulated-screw configurations and four of the thirty-two parallel-screw configurations failed. Osteonecrosis developed after five (14%) of the thirty-seven fractures treated with screw fixation alone and two (8%) of the twenty-five fractures treated with a fixed-angle device (Table II).

None of the four nondisplaced fractures failed to unite, and there were no cases of osteonecrosis in that group. Therefore, the rates of osteonecrosis and aseptic nonunion associated with the fifty-eight displaced fractures were 12% and 16%, respectively. Of the fifty-nine good-to-excellent reductions, eight (14%) were followed by nonunion and seven (12%), by the development of osteonecrosis. Two of the three fair reductions were followed by a nonunion (Table III). Five of the seven patients with osteonecrosis eventually underwent a total hip arthroplasty. Three of the nine fractures with an aseptic nonunion were treated with total hip arthroplasty, and two were managed with a hemiarthroplasty. Three fractures that had been initially treated with screw fixation had revision to a fixed-angle device (one sliding hip screw, one angled blade-plate, and one dynamic condylar screw), and all subsequently united. One nonunion of a fracture that had been treated initially with a dynamic condylar screw was revised with use of an angled blade-plate, and it healed two months later. The one infected nonunion eventually was treated with a resection arthroplasty.

The eleven fractures that were treated with open reduction had, by definition, a capsulotomy. Three additional displaced fractures treated with closed reduction and fixation also received a capsulotomy. None of the nondisplaced fractures were treated with either a capsulotomy or aspiration. Therefore, fourteen (23%) of the sixty-two fractures were treated with a concomitant capsular decompression at the time of the initial surgery. At the time of the most recent follow-up, osteonecrosis had developed

TABLE II Number and Type of Complications According to the Type of Implant Used to Fix the Vertical Femoral Neck Fractures

	Implant *(no. of fractures)*				
	Cannulated Screws	Dynamic Hip Screw	Cephalomedullary Nail	Dynamic Condylar Screw	Total
Nonunion	7	1*	1	1	10
Osteonecrosis	5	1	1	0	7

*One nonunion of a fracture treated with a dynamic hip screw was associated with a deep postoperative infection.

TABLE III Number and Type of Complications According to the Quality of the Reduction of the Vertical Femoral Neck Fractures

	Reduction *(no. of fractures)*			
	Excellent	Good	Fair	Poor
Nonunion	3*	5	2	0
Osteonecrosis	3	4	0	0

*One nonunion occurred concomitantly with osteonecrosis in a patient treated with a dynamic hip screw and was associated with a deep postoperative infection.

at the sites of two of the fourteen fractures that had been treated with a capsulotomy and five (10%) of the forty-eight fractures that had not. This difference was not significant.

Discussion

In this series, contemporary internal fixation methods for Pauwels type-3 vertical femoral neck fractures had a reasonable union rate (84%) with a low prevalence of osteonecrosis (11%). This may be attributable to the healing potential and excellent bone quality in most younger patients[9,10]. It is notable that the cohort was relatively young and the vast majority of fractures were displaced. A recent clinical study[11] and a recent meta-analysis[12] showed that older patients with poorer bone quality may have a higher tendency for nonunion, with rates of >30%, and poorer outcomes.

As had been observed in the vast majority of studies on the subject[1-3,7,13-15], we found that the quality of the reduction had an impact on the risk of nonunion, with two of the three fair reductions but only 14% of the good-to-excellent reductions followed by a nonunion. It was previously shown that two important predictors of failure of fixation of a femoral neck fracture were varus reduction and the surgeon's perception that attaining a reduction was difficult[13]. A recent review of the results of internal fixation of femoral neck fractures in 102 patients between fifteen and fifty years of age showed that posterior comminution, poor reduction, and improper screw placement were the most important factors contributing to nonunion[14]. Specifically, varus reduction and inferior displacement of the proximal fragment recently were found to adversely affect union rates in a series of thirty-nine patients with a femoral neck fracture[15].

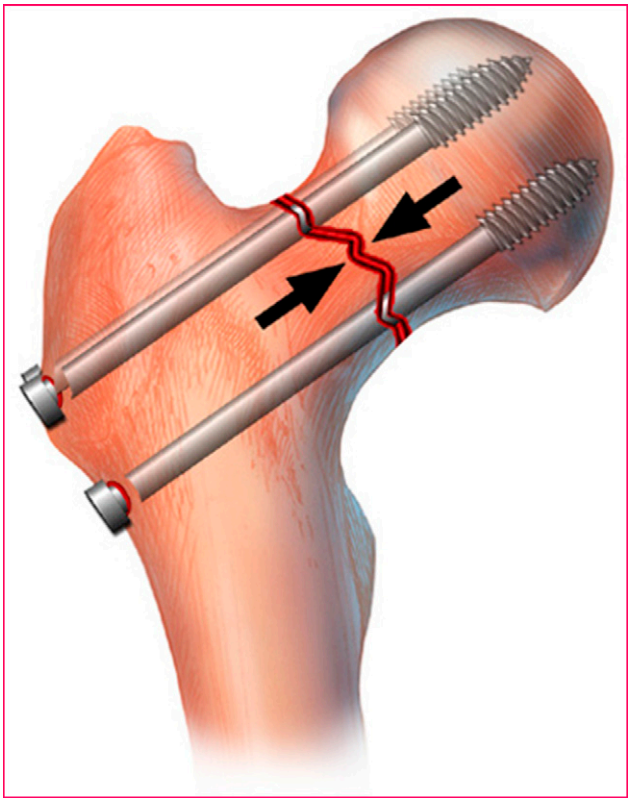

Fig. 2-A

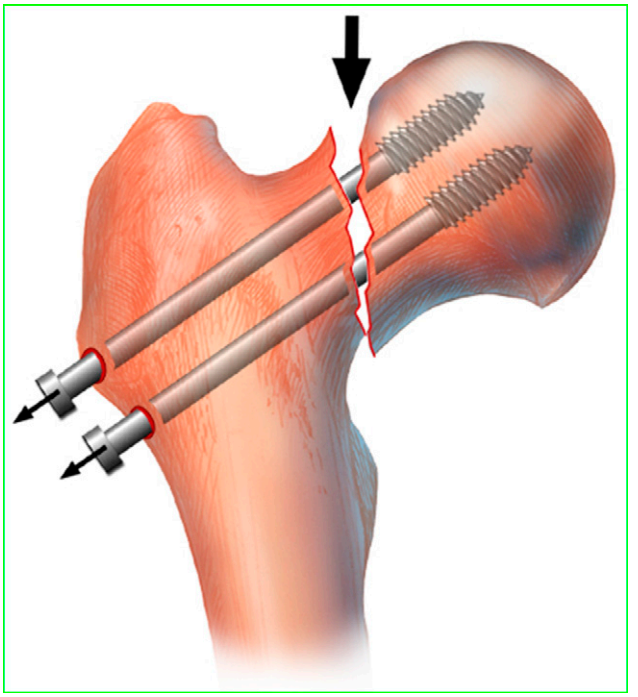

Fig. 2-B

Fig. 2-A Schematic representation of a vertical femoral neck fracture treated with three cannulated screws. The arrows indicate the direction of slide/compression of the fracture fragments along the shafts of the partially threaded cannulated screws. **Fig. 2-B** Schematic representation of a vertical femoral neck fracture treated with three cannulated screws that are now failing. The large bold arrow indicates the direction of shear force expressed at the fracture site. The small arrows indicate the directional slide of the screws.

Subanalysis of the fifty-eight displaced fractures in our series showed the rate of subsequent osteonecrosis to be 12%. The difference in the rate of osteonecrosis between those who had (14%) and those who had not (10%) received a capsulotomy was small; however, our sample size was too small for us to make definitive conclusions about the value of capsulotomy.

All of our patients were treated within twenty-four hours after the injury. However, the exact time to treatment is difficult to ascertain. We were unable to evaluate the effect of treatment times of less than twenty-four hours on outcomes, as detailed timing records were not available. A recent study of 102 patients showed that a delay in surgery of greater than forty-eight hours had no influence on osteonecrosis rates[14]. In another series, of thirty femoral neck fractures, there was no difference in osteonecrosis or nonunion rates between patients treated within twelve hours after the injury and those treated more than twelve hours after the injury[1].

With regard to the impact of implant type on nonunion rates, 19% of the fractures treated with screw fixation in our series compared with 8% treated with a fixed-angle device progressed to aseptic nonunion (Figs. 2-A and 2-B). This difference was not significant ($p = 0.29$), and the rates of osteonecrosis were also similar for the two device categories. Biomechanically, it has been shown that a sliding hip screw device is stronger than three parallel cancellous screws for the treatment of basicervical fractures, the orientation of which is similar to but more distal than that of Pauwels type-3 fractures[4,16]. A recent biomechanical study showed the construct stiffness of fixed-angle devices to be superior to that of cannulated screws alone for the fixation of a Pauwels type-3 fracture in cadaveric femora[17]. Stability and the quality of reduction appeared to influence the rates of adverse outcomes in our series.

Our overall nonunion rate of 16% was higher than that reported in a recent large series of femoral neck fractures in young patients[3] and supports the theory that these type-3 fractures experience shear and may demonstrate a higher rate of varus, shortening, and nonunion. Haidukewych et al. reported a nonunion rate of 8% overall but did not classify fracture verticality when they reported the outcomes[3]. In their series, anatomic reductions were associated with a 4% rate of aseptic nonunion. If one compares that series, which encompassed all types of femoral neck fractures, with the current series, in which the nonunion rate was about three times higher, it appears that the vertical fracture subcategory is more problematic. This is the case despite a very high percentage of anatomic reductions and the accurate performance of internal fixation by experienced traumatologists in our series. The difficulty in comparing our results with those of historical controls is the fact that, to our knowledge, no one has previously classified fracture verticality when reporting outcomes in large series. Ideally, we would have preferred to analyze the nonunion and osteonecrosis rates for all femoral neck fractures treated at our institutions and compared outcomes on the basis of fracture verticality; however, these data were not available in sufficient detail for us to draw definitive conclusions. Therefore, we chose to analyze the most vertical, or "worst-case-scenario," Pauwels type-3 fractures in an effort to demonstrate the impact of fixed-angle support on this theoretically high-shear fracture pattern.

The weaknesses of this study include the retrospective methodology, the variety of implants that were used, and the multiple surgeons involved. However, this fracture pattern is rarely encountered, making it difficult to obtain a large enough series to study. The strengths of this study include the relatively large number of cases treated with early accurate reduction and the good clinical and radiographic follow-up.

In conclusion, Pauwels type-3 femoral neck fractures are problematic to treat, with nonunion rates higher than those reported for historical controls. Despite excellent reduction, timely surgery, and accurate implant position in a relatively young patient cohort with good bone quality, the mechanical failure rate was 19% for fractures treated with cannulated screws alone and 8% for those treated with a fixed-angle device. These nonunion rates suggest that these fractures may experience more shear than do more horizontal fractures; however, our data do not allow us to draw any definitive conclusions about the best form of surgical stabilization. Larger, multicenter, prospective, randomized series are warranted to determine the optimal fixation strategy for this problematic fracture. ■

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