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RESEARCH ARTICLE
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MANAGEMENT OF HIGH PAUWELS' FEMORAL NECK FRACTURES IN YOUNG ADULTS

Dr Reyaz Ahmad Dar[1], Dr Rasiq Rashid[2], Dr Imtiyaz Ahmad Beigh[3*], Dr Subqat Farooq[4]

[1,2,3*,4]Department of Orthopaedics SKIMS MCH Srinagar Jammu and Kashmir, India.

***Corresponding Author:** Dr Imtiyaz Beigh
*Senior resident Orthopedics SKIMSMC Hospital Bemina Srinagar, Imtiyaz.gmc@gmail.com

INTRODUCTION

Femoral neck fractures are frequent orthopedic injuries with treatment and costs presenting a major public health problem. The optimal treatment is debated based on patient variables, fracture displacement, and fracture pattern. When proceeding with internal fixation, there are challenges in both young and old patients. Optimizing stability of femoral neck fracture fixation is important in obtaining a successful outcome. The mechanical problems and strategies for achieving optimal stability differ depending on patients' age and type of fracture.

Pauwels classified femoral neck fractures into three categories on the basis of their degree of verticality (Fig. 1). 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 primarily experience compression with loading. The classifcation relates the prognosis to the angle of the fracture plane—as the angle increases the fracture instability increases and complications of fracture healing and fxation are more likely.

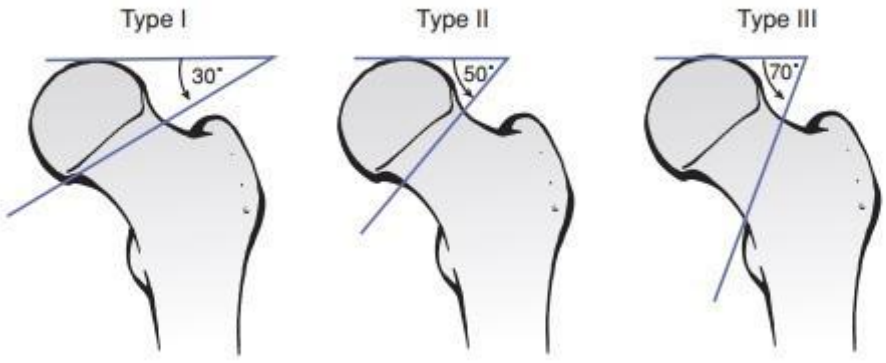

Fig. 1 Pauwel Classification

Both gravity and hip abductor force vectors result in 2 dominant forces acting on the femoral neck. A force parallel to the long axis of the femur creates shear stress across the fracture plane. The other force lies parallel to the long axis of the femoral neck. Femoral neck fractures in younger adults usually result from high-energy trauma.

These high-energy injuries may involve a vertical fracture pattern resulting in a high shear load at the fracture site, and this may be associated with high internal fxation failure rates (Fig. 2).

Fig 2. X-ray of a16 year old young patient showing Pauwels type 3 fracture

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. The primary blood supply to the femoral head is the deep branch of the medial femoral circumflex artery. It anastomoses anteriorly with branches of the lateral femoral circumflex artery and branches of the obturator artery. Additional anastomoses occur with the superior and inferior gluteal arteries, and internal pudendal artery. Although there is wide variability, the average femoral neck shaft angle measures 127° and the average femoral- neck anteversion measures13°.

Strategies for optimizing fixation stability in the young age group include placing additional screws at right angles to the fracture plane and medial buttress plate augmentation. Rates of osteonecrosis and nonunion have been reported as ranging from 10% to 45% and from 10% to 30%, respectively.

Cannulated screw fxation is a widely accepted technique for transcervical femoral neck fracture fxation because it is simple and minimally invasive. A number of biomechanical and clinical studies have attempted to identify the ideal configuration and number of screws for optimal fixation to resist axial bending and torsional forces passing across the hip joint. Fracture stability increases when increasing from 2 to 3 screws. The optimal construct for osteoporotic femoral neck fixation is an inverted triangle configuration with 3 parallel screws. The addition of a fourth screw has been shown to significantly increase construct strength in femoral neck fractures with significant posterior cortical comminution.

Femoral neck shortening following femoral neck fracture fixation with cancellous screws is common and results in a significant negative impact on the patient's physical function.

Technique of internal fixation using nonsliding constructs minimizes femoral neck shortening. These constructs include a sliding hip screw or a dynamic condylar screw. To our knowledge there have been no clinical series in North India analyzing the results of various fixation strategies—i.e., comparing screw fixation alone with a fixed-angle device in Pauwel's type 3 fractures in younger age group.

The purpose of this study was therefore to evaluate series of Pauwels type-3 femoral neck fractures

in young adults and compare the outcomes and complications associated with the treatment of these fractures by various internal fixation devices and strategies.

Materials and Methods

Twenty five patients with Pauwels type-3 femoral neck fractures in skeletally mature patients were treated with internal fixation at a tertiary care hospital in North India. Radiographs were reviewed and fracture verticality was measured with a goniometer according to the method of Pauwels. Only transcervical fractures with >70 degrees 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 erticality 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 fifteen to thirty five years, with a mean age of twenty-three years. Sixteen patients were males and there were 9 female patients. All patients had a unilateral fracture. All fractures were classified as type-31B2.3 according to the system of the Orthopaedic Trauma Association(OTA). All patients were followed to union or revision surgery, with a mean duration of follow-up of eighteen months (range, twelve to twenty four months). After institutional review board approval was obtained a, clinical and radiographic data were reviewed and results, complications, and the need for revision surgery were analyzed. Ten 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.

Twenty fractures were displaced, and five were nondisplaced. Fourteen fractures were treated with Cannulated screw fixation, and eleven 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, eight were treated with a dynamic hip screw and three with a dynamic condylar screw (Table I).

Table 1. Quality of reduction with different implants

IMPLANT	EXCELLENT	GOOD	FAIR	POOR	TOTAL
CCS	5	4	3	2	14
DHS	3	2	1	2	8
DCS	2	-	1	-	3

Three were treated with open reduction and internal fixation (with direct visualization of the fracture fragments), and twenty were treated with closed reduction and internal fixation. Generally, at our institution, fractures were reduced under direct visualization if closed reduction was seen to be imperfect under fluoroscopic scrutiny in two planes. Two displaced fractures were treated with a capsulotomy. Intra-op quality of reduction was assessed by identifying Lowell's S / reverse S curves and Garden alignment index. Haidukewych et al. method was used to assess the quality of femoral neck reduction. 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). Osteonecrosis was classified radiographically with use of the method of Ficat.

Results

Sixteen (64%) of the twenty five- fractures healed after the index operation without evidence of osteonecrosis or nonunion at the time of final follow-up. Osteonecrosis occurred after treatment of four (16%) of the twenty- five fractures, and there was a nonunion of five (20%) of the twenty-five fractures. Two patients had both of these complications. Three of the eight inverted triangle parallel cannulated-screw configurations and one of the six cross-screw configurations had nonunion. Osteonecrosis developed after three (21%) of the fourteen fractures treated with screw fixation alone and one (9%) of the eleven fractures treatedwith a fixed-angle device (Table II). There was one case of nonunion in the latter group.

Table 2. Complications with the use of different implants

COMPLICATION	CCS	DHS	DCS	TOTAL
NONUNION	4	-	1	5
OSTEONECROSIS	3	1	-	4

None of the five 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 twenty displaced fractures were 20% and 25%, respectively. Of the sixteen good-to-excellent reductions, one (8%) was followed by nonunion and one (8%), by the development of osteonecrosis. Two of the five fair reductions were followed by a nonunion. One fracture that had been initially treated with screw fixation had revision to a fixed-angle device and subsequently united.

Three fractures that were treated with open reduction had, by definition, a capsulotomy. Two 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. At the time of the most recent follow-up, osteonecrosis had developed at the sites of two of the five fractures that had been treated with a capsulotomy and two of the twenty (10%) of the twenty fractures that had not. This difference was 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 (16%). This may be attributable to the healing potential and excellent bone quality in younger patients. It is notable that the cohort was relatively young and the vast majority of fractures were displaced. A recent clinical study11 and a recent meta-analysis showed that older patients with poorer bone quality may have a higher tendency for nonunion, with rates of >30%, and poorer outcomes. Quality of the reduction had an impact on the risk of nonunion. Four of the nine poor –to- fair reductions but only one out of sixteen of the good-to-excellent reductions were complicated 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.

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. 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 fracture15 Subanalysis of the twenty displaced fractures in our series showed the rate of subsequent osteonecrosis to be 20%.

The difference in the rate of osteonecrosis between those who had (40%) and those who had not (10%) received a capsulotomy was significant; 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 rates14. 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.

With regard to the impact of implant type on nonunion rates, four out of fourteen (28) % of the fractures treated with screw fixation in our series compared with one out of eleven (9%) treated with a fixed-angle device progressed to aseptic nonunion (Figs. 2 and 3). This difference was not significant ($p = 0.29$), and the rates of osteonecrosis were 21% and 9% respectively for the two device categories.

Fig 2. X-ray of a vertical femoral neck fracture treated with three cannulated screws.

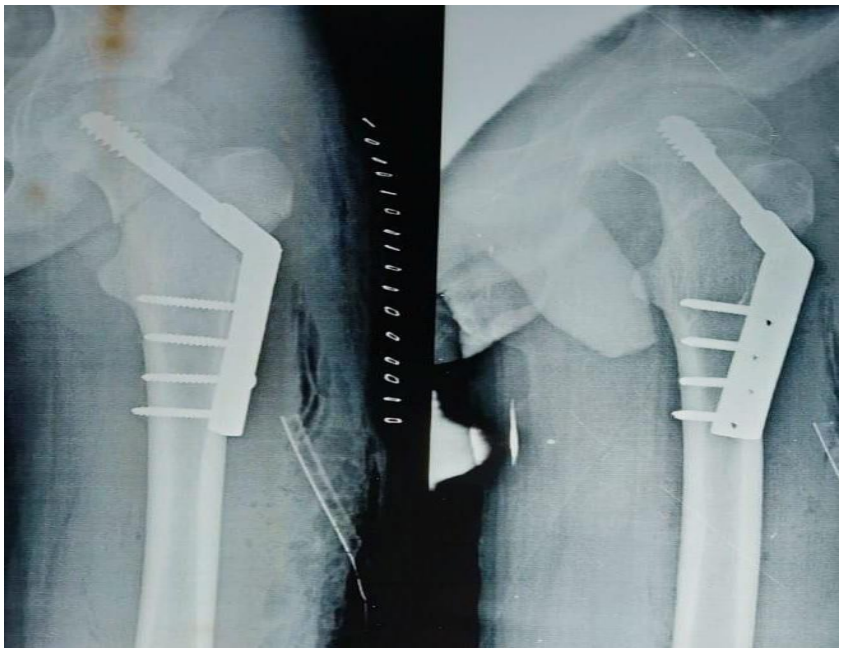

Fig. 3 Xray of a vertical femoral neck fracture treated with dynamic hip screw with blade plate system.

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. 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.

Our overall nonunion rate of 20 % was higher than that reported in a recent large series of femoral neck fractures in young patients 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. In their series, anatomic reductions were associated with a 4% rate of aseptic nonunion. Therefore, we chose to analyze the most vertical, or ''worst-case scenario,'' 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 smaller number of cases 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 its propective design and 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 28% for fractures treated with cannulated screws alone and 9% 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 con clusions 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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