Original Article

Four quadrant parallel peripheral screw fixation for displaced femoral neck fractures in elderly patients

Bhava RJ Satish, Atmakuri V Ranganadham[1], Karruppasamy Ramalingam, Sujit Kumar Tripathy[2]

Abstract

Background: The treatment options for displaced femoral neck fracture in elderly are screw fixation, hemiarthroplasty and total hip arthroplasty based primarily on age of the patient. The issues in screw fixation are ideal patient selection, optimal number of screws, optimal screw configuration and positioning inside the head and neck of femur. The problems of screw fixation may be loss of fixation, joint penetration, avascular necrosis of femoral head, nonunion, prolonged rehabilitation period and the need for second surgery in failed cases. We hereby present results of a modified screw fixation technique in femoral neck fractures in patients ≥50 years of age.

Materials and Methods: Patients ≥50 years of age (range 50-73 years) who sustained displaced femoral neck fracture and fulfilled the inclusion criteria were enrolled in this prospective study. They were treated with closed reduction under image intensifier control and cannulated cancellous screw fixation. Accurate anatomical reduction was not aimed and a cross sectional contact area of >75% without varus was accepted as good reduction. Four screws were positioned in four quadrants of femoral head and neck, as parallel and as peripheral as possible. Radiological and functional results were evaluated periodically. Sixty four patients who could complete a minimum followup of two years were analyzed.

Results: Radiologically, all fractures healed after mean duration of 10 weeks (range 8-12 weeks). There was no avascular necrosis. Nonanatomical healing was observed in 45 cases (70%). All patients except one had excellent functional outcome and could do cross-legged sitting and squatting. Chondrolysis with progressive head resorption was seen in one case, which was converted to total hip arthroplasty.

Conclusion: Closed reduction and cannulated cancellous screw fixation gives satisfactory functional results in large group of elderly patients. The four quadrant parallel peripheral (FQPP) screw fixation technique gives good stability, allows controlled collapse, avoids fixation failure and achieves predictable bone healing in displaced femoral neck fracture in patients ≥50 years of age.

Key words: Femoral neck fracture, osteosynthesis, four quadrant parallel screw fixation

Introduction

Despite ever-increasing literature on hip fracture, there are no authoritative and evidence-based guidelines for the management of displaced intracapsular femoral neck fractures (FNF).[1] A general lack of consensus exists among orthopedic trauma surgeons in the management of these fractures.[2] The decision making in hip fracture treatment depends on age, patient's co-morbidities, pre-fracture mobility status, associated injuries, bone quality, fracture configuration and pre-existing degenerative status of the joint.[3-6] The present consensus is that FNF in patients below 60 years of age should be treated with internal fixation, and arthroplasty should be reserved for elderly patients above 80 years, 60 to 80 years old patients with displaced FNF still remain a grey zone.[7] The surgical duration, bleeding, need of blood transfusion, infection and immediate postoperative mortality is considered less with internal fixation compared to arthroplasty.[8] However, fixation failure and reoperation rates are higher with internal fixation; thus, majority of orthopedic surgeons prefer prosthetic replacement.[9-11] Present guidelines favors total hip arthroplasty (THA) in active, independent patients aged >60 years and primary hemiarthroplasty (HA) for elderly, moribund patients with dependent living status.[12]

The functional results of arthroplasty however best done cannot equal that of a united FNF. Many of the daily

BRJ Ortho Centre, Coimbatore, Tamil Nadu, [1]Sree Ortho Clinic, Behrampur, Odisha, [2]KMC Hospital, Manipal, Karnataka, India

Address for correspondence: Dr. BRJ Satish Kumar, Arthroplasty and Trauma Surgeon, BRJ Ortho Center, 218 NSR Road, Saibaba Colony, Coimbatore, Tamilnadu, India.
E-mail: drbrjorthocentre@gmail.com

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functional activities of Asian patients require squatting and sitting cross-legged which cannot be performed with arthroplasty, and thus, every efforts of joint conservation should be aimed for. Fixation for FNF is usually performed with cancellous screws or Dynamic hip screw. The controversial factors in cancellous screw fixation are: method of reduction - open or closed, number of screws used – two, three or four, the configuration of screws – parallel or nonparallel, vertical or triangular fashion, the positioning of screws in the head – center of head or in the periphery and the addition of bone grafting – free fibula or quadratus femoris muscle pedicle grafting.

Several biomechanical analytical studies have assessed the stability after simulated fracture fixation on cadaveric femora with variable results.[13-19] The conventional AO fixation using three screws in apex proximal triangular configuration is generally practiced by several surgeons for fixing FNF.[20,21] In a radiographic review study of patients who underwent cannulated cancellous screw fixation for FNF, six different types of screw configurations were found: Triangular configurations, consisting of two parallel screws with a third screw placed either superiorly, inferiorly, anteriorly or posteriorly; and linear configurations with two or three screws in a vertical line.[22] In a multinational survey of 298 Orthopedic surgeons, it was found that 73% agreed on the use of three cannulated screws and more than half used the triangle with base inferior construct.[2] Patwa *et al*. in a biogeometric study of Indian femurs found that inferior half of femoral neck is narrower than superior half and recommended apex distal configuration for screw fixation.[20] Both in experimental and clinical studies, controversies exist regarding the ideal screw fixation method that can provide good stability and good clinical results respectively.

The area covered by the fixation device is important in any fracture fixation; more the area on either side of fracture, better is the stability. We felt that, by adding the fourth screw and keeping the screws in peripheral portion of the head and neck, the area of fixation can be easily increased in FNF fixation. Simple geometric projections and calculations revealed a dramatic increase in the volume occupied by the four peripheral screws compared to three screws [Table 1]. With the aim of providing higher success rate in a large group of patients using a single uniform procedure, we started four screw fixation. We report the outcome of four quadrant parallel peripheral screw fixation technique in active, independent patients aged ≥50 years with displaced FNF.

Materials and Methods

One hundred and eighty patients with displaced fracture neck femur aged 50 years or more who were operated for displaced femoral neck fracture in our center from January 2005 to December 2008 were included in the study. The patient selection criteria for four cannulated screw fixation were: age 50 years or more, displaced fracture neck of femur (Garden Grade III and IV), presence of primary compressile trabeculae in hip anteroposterior (AP) radiograph, no radiographic evidence of pathological fracture, and independently mobile patient without neuromuscular disorder or cognitive impairment and without any metabolic bone disease. There was no upper age limit for patient selection.

All patients were prospectively followedup. Sixty four patients who completed a minimum of two year followup were included in the study. There were 34 females and 30 males. The mean age of patients was 60 years range (range 50-73 years). The mean time interval between injury and surgery was 48 hours (range eight hours-seven days). Sixty two fractures were subcapital and two were transcervical.

Operative procedure

FNF reduction was attempted by gentle traction with hip in neutral extension, neutral or 10 to 15° of abduction, neutral or 10° of internal rotation with patient on fracture table [Figure 1]. The reduction was checked in both AP

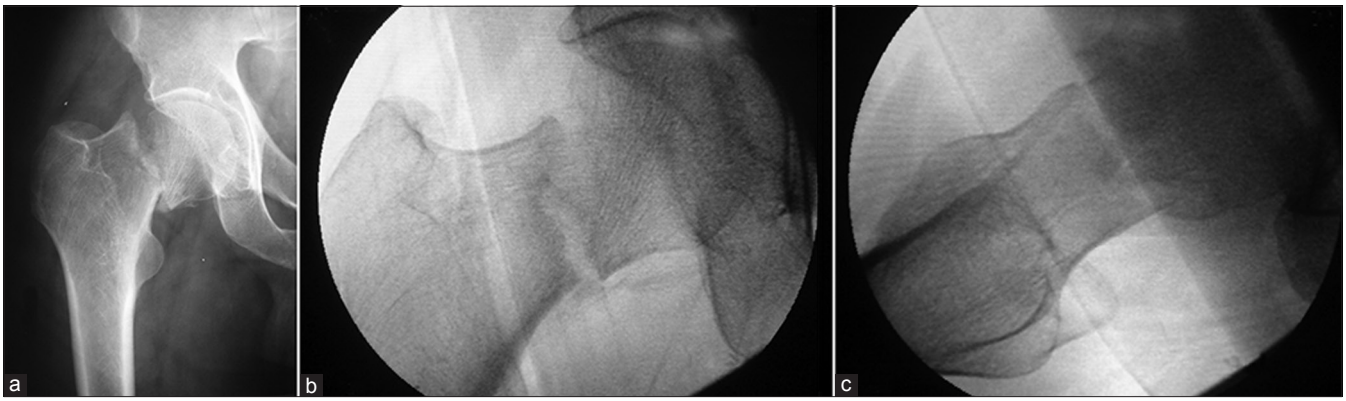
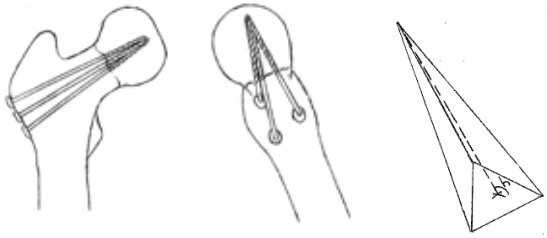
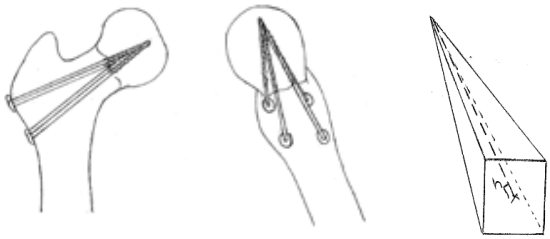
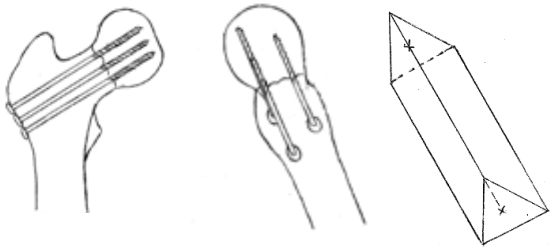
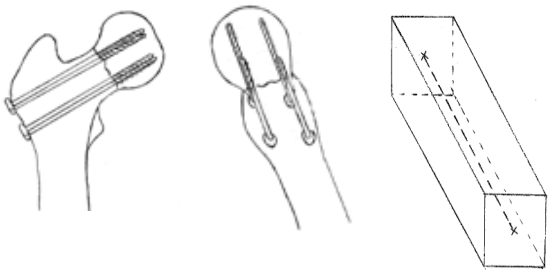


Figure 1: (a) X-ray right hip joint showing garden IV femoral neck fracture, (b and c) anteroposterior and lateral fluoroscopic views showing closed reduction

Table 1: The three or four screw configurations, corresponding projected geometric designs and the area covered. The converging patterns have lower volume than parallel patterns with four quadrant parallel peripheral pattern having the maximum area covered with the screws

Screw configuration	Antero-posterior view	Lateral view	Geometric diagram	Volume (area covered by the screws)
3 screws converging				Triangle base pyramid 1/6 lbh
4 screws converging				Rectangle base pyramid 1/3 lbh
3 screws parallel				Triangle base prism 1/2 lbh
4 screws parallel				Rectangle base prism (cuboid) lbh

Note: Height (h) represents the length of the screw, length (l) represents the distance between superior and inferior screws and breadth (b) represents distance between a posterior screw and anterior screw

and lateral views of image intensifier. Accurate anatomical reduction was not aimed. A cross sectional contact area of more than 75% without varus deformity was considered as satisfactory reduction. If the reduction was unacceptable, direct manipulation or flexion technique was used.

The inferior screws were placed first. The starting point for the inferior screws was usually at the level of lesser trochanter. Since the lateral surface of femur is convex, the starting point often slips anterior or posterior. To avoid this, a pilot hole was made with 3mm K wire perpendicular to shaft surface in the exact needy location i.e., posterior to mid-lateral cortex at the level of lesser trochanter for inferior posterior (IP) screw. The pilot hole was enlarged with 3.5- or 4-mm drill bit, which was directed in oblique direction as required to make an oval hole in the cortex. A nonthreaded 2-mm guide wire was taken in the hand and pushed into the desired screw trajectory: parallel and just superior to the inferior border of the neck in the anteroposterior view, parallel and just anterior to the posterior border of the neck in the lateral view [Figure 2a]. With bigger pilot hole, the guide wire could be easily manipulated in both the planes in the required direction. The guide wire was hand pushed up to head-neck junction. After positioning the guide wire in the desired path, the same was drilled into the head 2mm short of the articular margin. Tapping of the lateral cortex was done for screw entry. No drilling or tapping was done in the head or neck region. A 7-mm diameter, 16-mm partially threaded cannulated cancellous screw of adequate

length was passed over the guide wire and tightened noting the compression across fracture site [Figure 2b]. If the neck diameter was smaller, a 6-mm diameter screw was used. For inferior anterior (IA) screw, pilot drill hole was made exactly at the same level of IP screw, anterior to the mid lateral cortex of femur. The guide wire was passed free hand, parallel to the IP screw in the AP view and parallel and just posterior to the anterior cortex of the neck in the lateral view [Figure 3]. The superior posterior (SP) screw was placed just below and parallel to the superior border of the neck in the AP view and parallel to the IP screw in the lateral view [Figure 4]. The superior anterior (SA) screw was placed parallel to the SP screw in the AP plane and parallel to the IA screw in the lateral view [Figure 5].

In this fashion, all the four quadrants i.e., inferior posterior, inferior anterior, superior posterior and superior anterior quadrants of the femoral heads were stabilized with the neck/trochanter fragment. The screws were placed as much parallel as possible and as peripheral in the neck as possible. We term this fixation as four quadrant parallel peripheral (FQPP) fixation [Figure 6]. The screws could diverge from the neck into the head but convergence of the screws towards head center was not accepted. The mean duration of surgery was 42 minutes (range 30-55 minutes).

Postoperatively, the limb was kept in 10-15° of abduction with knee flexed at 10-20°. Postoperative radiographs were obtained on the first postoperative day. The patient was encouraged to do static quadriceps, terminal knee extension and active assisted/active straight leg raising (SLR) exercises once anesthesia weans off. Patient was advised for opposite side turns in the bed in the immediate postop period. Twenty four hours after surgery, patient was made to sit up on the bed side and nonweight bearing (NWB) walking was started. On 2nd postop day, transfer to high seat, mobile western commode was allowed. Patients were discharged from hospital 48-72 hours after surgery.

The patients were followedup clinically and radiologically after three weeks, six weeks, three months, six months, twelve months and after two years. Partial weight bearing (PWB) was allowed after three weeks and full weight bearing (FWB) was allowed after radiographic union was evident. Radiologically fracture union was defined as continuity of at least three cortices in AP and lateral views without any fracture gap. Clinically fracture was considered as healed when there was no local tenderness and patient could do full weight bearing without any support. Stair climbing and hip abductor strengthening exercises were initiated at six weeks. Once the fracture was healed, patients were encouraged to sit on the floor cross legged and to do squatting. The functional outcome was evaluated with a new six-point score [Table 2]. The one year score was taken as final functional outcome.

Results

Radiologically, all fractures healed [Figure 7]. The mean healing time was 10 weeks (range 8-12 weeks). Screw back

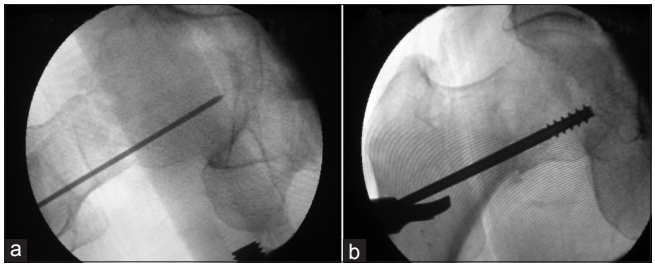


Figure 2: Fluoroscopic views (a and b) showing inferior posterior quadrant guide wire and screw

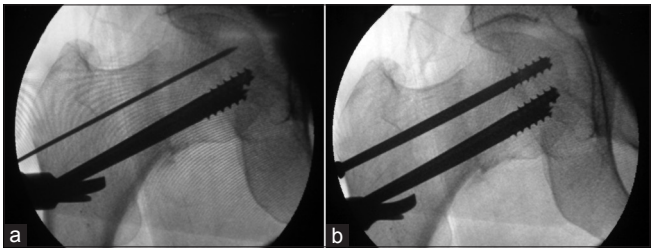


Figure 4: Fluoroscopic views (a and b) showing superior posterior quadrant guide wire and screw

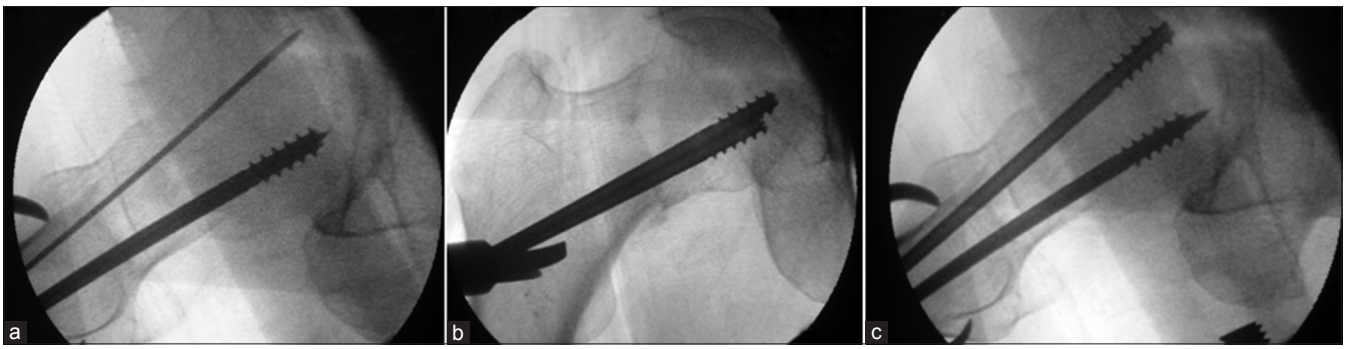


Figure 3: Fluoroscopic views (a-c) showing inferior anterior quadrant guide wire and screw

Table 2: A six-point functional outcome scoring system for asians after hip surgery

Function	Score 0	Score 0.5	Score 1	Patient score
Pain at hip area	Moderate or severe	Mild	No pain	
Walking	Significant limp with aid	Mild limp with aid	No aid No Limp	
Independent mobility outside the house	Not possible	-	Possible	
Sitting cross legged in the floor	Not possible	Incomplete	Complete	
Squatting	Not possible	Incomplete	Complete	
Climbing stairs	Not possible	Using hand rails or support	Without any support	
Total score	-	-	-	

Scoring analysis = Excellent-5 or more, Good-4, 4.5 points, Fair-2 to 3.5 points, Poor-less than 2, Minimum score-0, Maximum score-6

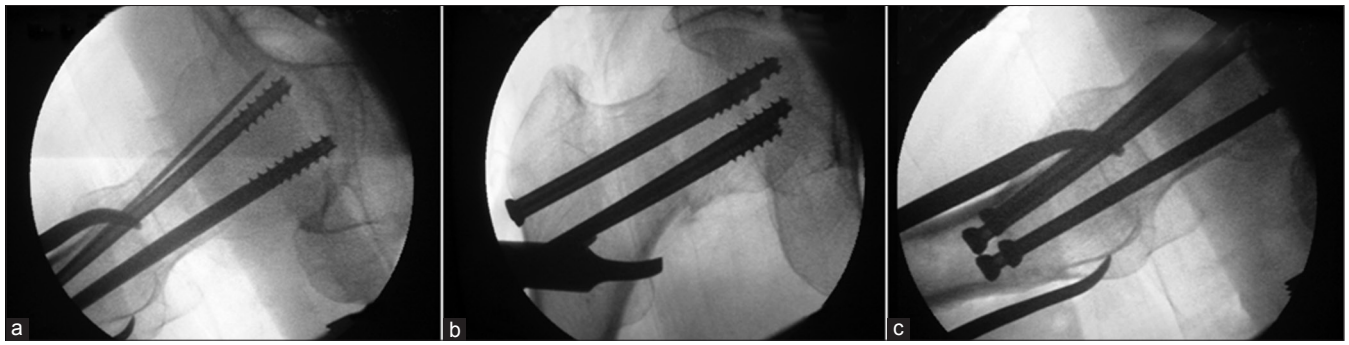


Figure 5: Fluoroscopic views (a-c) showing superior anterior quadrant guide wire and screw

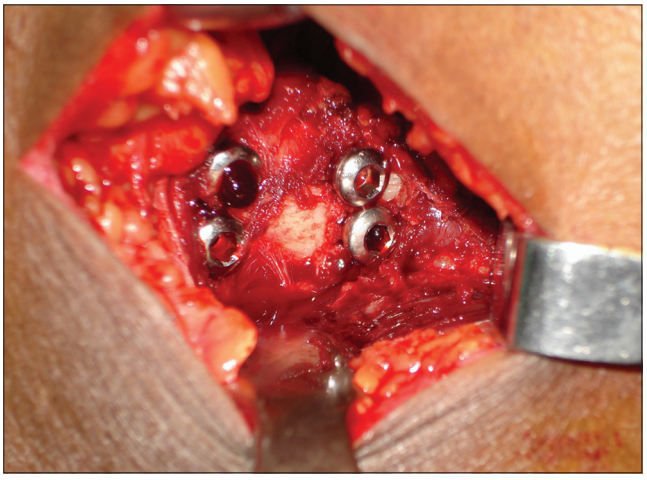


Figure 6: Peroperative photograpyh showing screws head configuration at entry point in four quadrant fixation

out indicating fracture collapse and coxa breva was seen as early in the immediate postoperative X-ray. The average distance of screw back out was 6mm (2-12mm). No patient developed AVN changes in the followup period of 2 years.

Nonanatomical healing or malunion was observed in 45 cases (70%). Various components of malunion observed were coxa breva (n = 35), coxa valga (n = 22), rotational (n = 18), translational (n = 12) and coxa vara (n = 1) [Figure 8]. If there was cortical reduction at one border of the neck with step in another border, it was considered as rotational malunion. If there was a cortical step at both superior and inferior borders of neck, it was considered as translational malunion.

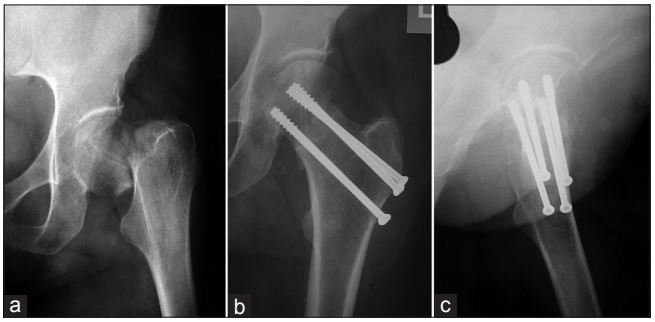


Figure 7: X-ray left hip joint anteroposterior view (a) showing femoral neck fracture, (b,c) anteroposterior and lateral views showing union after four quadrant parallel peripheral screw fixation

The functional score was excellent in 50 hips (78.2%), good in 13 hips (20.3%) and poor in one hip (1.5%). The single patient with poor outcome had chondrolysis with progressive femoral head resorption. Another patient had coxa vara with screw penetration. Both patients had painful hip with antalgic gait. The first patient underwent uncomplicated cemented THA [Figure 9]. Screw removal was done in the second patient resulting in complete pain relief. Except for these two patients, implant removal was not done in any other hip. Other than these two patients, no patient had antalgic or Trendelenburg gait.

All patients, except for the THA patient, could do cross legged sitting in the floor and squatting. Cross legged sitting was complete in 48 hips (flexed knee close to the floor) and partial in the rest. Squatting was complete in 54 hips (thigh close to the abdomen) and partial in the rest. All patients could climb stairs. Fifty two patients achieved

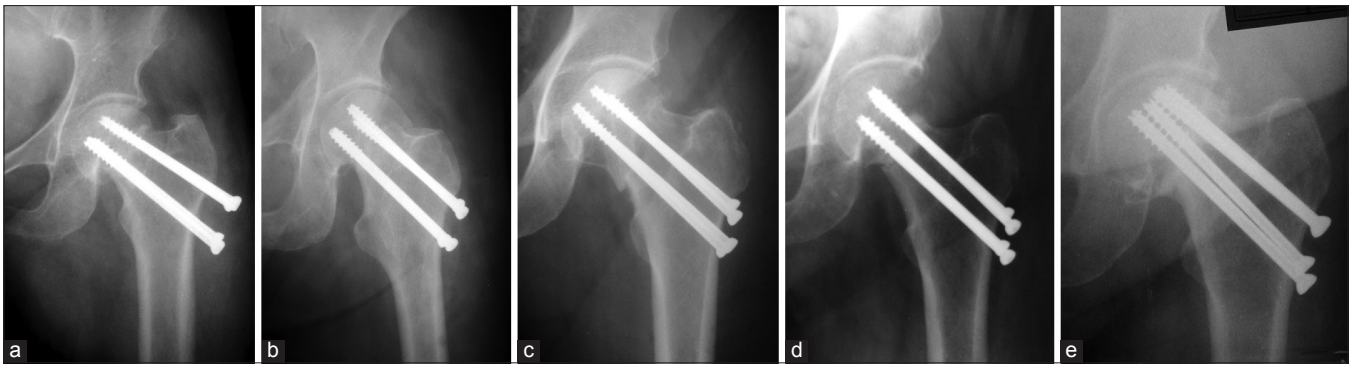


Figure 8: X-ray hip joint anteroposterior view showing healed femoral neck fracture (a) coxa breva (b) coxa valga (c) rotational malunion (d) translational malunion (e) coxa vara

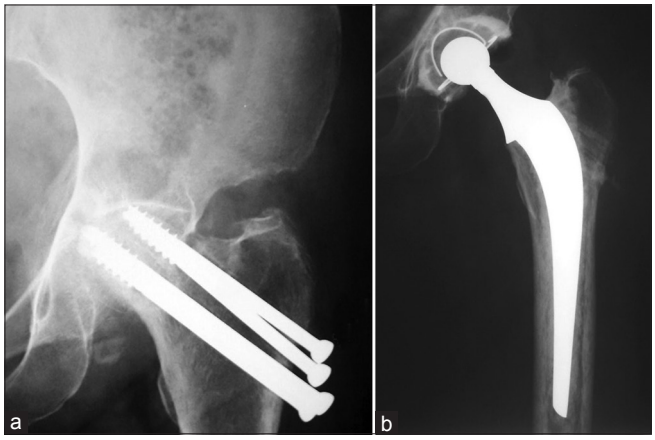


Figure 9: X-ray hip joint anteroposterior view (a and b) showing head resorption and total hip arthroplasty

maximum functional score at the end of 6 months which was maintained in the subsequent followup. Eleven patients continued to show improvement in sitting cross legged and squatting after 6 months that improved their final score at 1 year.

Discussion

Since intracapsular fracture neck of femur heals by primary healing, along with stability in coronal and sagittal planes, absolute rotational stability is necessary across the fracture site.[23-27] The proximity of polyaxial hip joint and the location of fracture at junction of lower limb and trunk results in variety of forces acting across the fracture, even in a bed bound patient. The commonly used screw fixation construct in FNF may be imperfect with one or more of technical flaws: Unacceptable reduction (less contact area), lack of parallelism, convergence towards head center, crowding of screws in small area, inadequate screw length, repeated drilling into the head weakening screw purchase and leaving fracture gap. Loading on imperfect mechanical construct can result in uncontrolled collapse, tilting of head into varus, loss of contact, nonunion and screw penetration into the joint. The key therefore is to provide good stable construct that can withstand the "routine" strains, still maintain contact between the fracture ends, provide stability and allow healing.[28]

The FQPP construct gives better initial stability, allows better controlled collapse, improves stability with passing time because of increased contact and promotes union. The four screws which are placed in the periphery of the neck act as four struts or pillars and provide excellent stability. Even if the screw purchase is suboptimal in osteoporotic bones, FQPP screws act as internal splints. The good peripheral or circumferential fixation does not allow the head to settle in varus or any angulations and eliminates the detrimental rotational strain. Since the screws are parallel, they permit controlled collapse maintaining the contact at any point of time. The problems of three screw fixation can be of twofold: the adequacy of fixation especially in older population and ability for controlled collapse. This is especially common when there is lack of parallelism between the three screws and the apex screw is not in the center of two basal screws.[29] During daily activities, the loads on femoral head alternate anteriorly and posteriorly. If there is less support on the anterior quadrants, loading can result in head tilting into varus anteriorly with screw penetration in the posterior quadrant of the head. If there is less support on the posterior quadrants, loading can result in head tilting into varus posteriorly with screw penetration in the anterior quadrant of the head. In FQPP construct, there is uniform load distribution across all areas of the femoral head.

There was varying degrees of screw backout in almost all cases. This could be seen as early as 24 hours after surgery, because patients were allowed to do bed side activities and early SLR exercises. This controlled collapse or fracture settling is similar to that of distal radius fracture or intertrochanteric fracture and can be considered as a good sign provided the reduction and screws orientation are maintained.

In the 70 year old patient who developed femoral head

fragmentation and resorption, cemented THA was performed 14 weeks after the index surgery. There were no signs of infection, inflammation and tumor preoperatively. Histo-pathological study of the retrieved loose bony fragments did not show any pathology. We failed to attribute any particular reason for this complication in this case.

We have evaluated the clinical outcome with a new six point hip functional score [Table 2]. The existing scoring systems either do not consider sitting cross legged and squatting or cumbersome for quick clinical application. Assessment at any point of time in the postoperative period should convey the functional status since the results could not be expressed as an improvement over the preoperative score, which is not possible in fracture cases. This new hip clinical score is based on the routine clinical observations or questions that are done with patient during their clinical visit. Pain, range of motion in the form of sitting cross legged and squatting, functional activity in the form of walking, stair climbing and individual mobility outside the house were assessed. In elderly patients, basic functional assessment may be sufficient rather than advanced functional assessment, as the individual functional capacity is highly variable depending on underlying general fitness. The assessment with the new score is fast and can be done by surgeon or any trained health professional. Being a single digit numeric score, we feel it easily reflects the postsurgical functional results.

The results of our study are relevant in general and in particular to Indian population. Many Indian patients come from rural background, where they do physical work even in advanced age. With healed FNF, "unsupervised" physical work, sitting in floor, squatting and regular life style can be allowed. Unlike replacement arthroplasty, prolonged medical supervision or followup is not necessary. Most of the patients do not have insurance cover, the cost of FNF fixation surgery is less than that of HA or THA. While factors like high cost, lack of surgical expertise, lack of operation theatre facilities and fear for dislocation may force surgeon against THA option, fear for fixation failure and nonunion may force surgeons against fixation option, leaving the lone HA option which is not suitable for all age groups. With high success rate, FQPP can be picked as first choice over THA or HA, especially in the age group between 50 to 70 years. While revising a failed closed screw fixation surgery into THA is almost like a virgin hip surgery, converting painful or failed hemiarthroplasty into THA is difficult and akin to revision THA on several occasions with suboptimal results.

The advantages of FQPP technique are many: good clinical outcome, a modification of existing technique which surgeons are familiar, small learning curve, simple routine theatre setup, short surgical time and low expenditure. The only disadvantage is the initial difficulty in optimal screw positioning. The technique may appear demanding, but with adherence to key surgical steps, it can be mastered easily. The strengths of our study are that it is a prospective study, has relatively large sample population and has adequate followup. The weakness of the study is assessment with a new hip score.

Few myths regarding FNF should be addressed. The first and foremost myth is that an accurate anatomical reduction is essential for fracture union and FNF cannot malunite. As shown from this study, anatomical reduction in FNF is neither mandatory for fracture healing nor necessary for satisfactory function. We achieved anatomical reduction of FNF on the operation table only in 50% cases. However, "near" anatomical healing was seen only in 30% of cases. About 70% of healed fractures had one or more elements of malunion. This should be viewed as "nonanatomical" healing rather than malunion. The changes in anatomy are increased neck shaft angle, few millimeters of displacement or collapse and few degrees of rotation. In FNF, this nonanatomical healing can hamper some function like full cross legged sitting in the floor and full squatting, but patients can walk comfortably without pain, limp and walking aid. FNF is intracapsular but not intraarticular fracture. The emphasis should be on perfect fixation rather perfect reduction.

The tips in getting acceptable reduction in FNF are minimal traction, neutral or mild internal rotation, neutral or mild abduction and understanding the three dimensional anatomy before manipulation. Heavy traction, vigorous manipulation and excessive internal rotation are common pitfalls that prevent reduction. Except for varus orientation, malreductions like valgus orientation, single cortical step and bicortical steps should be accepted. Repeated manipulations should not be done to reduce the opening of anterior or posterior cortex, which could be easily achieved with screw compression. A cross sectional fracture contact area of 75% or more without coxa vara should be the aim of reduction. The second myth is about the synovial fluid bathing the fracture surfaces resulting in FNF nonunion. Amongst synovial joints the largest synovial fluid volume is that of knee joint. All intraarticular fractures involving femoral condyle and tibial condyle can heal with simple splinting. While these intraarticular fractures can heal by "secondary" healing without any surgical intervention, FNF requires implant fixation stability for "primary" healing. The third myth is that most if not all FNF results in AVN femoral head. Vigorous traction and manipulations, multiple un-physiological manipulations and open reduction may result in AVN. We have accepted nonanatomical reduction rather than resorting open reduction in our cases. The fracture *per se* does not result in AVN at least in older

population, where the injury is of low velocity nature and the capsule is intact. In India, several patients with untreated FNF present late, walking with painless limp. Their X-rays reveal nonunion and neck resorption but not AVN. The average time delay between injury and surgery in our patients was 48 hours. The longest gap was seven days. No patient developed AVN after fixation in our study.

In conclusion, four quadrant parallel peripheral screw fixation technique gives good clinical results in displaced femoral neck fractures in large group of patients aged 50 years or above. This technique, a slight variation of the regular three screw fixation construct, provides excellent stability necessary for primary or endosteal healing of these fractures. With high healing rates, minimal complications and the availability of rescue surgery in the form of prosthetic replacement, this fixation should be attempted in all possible cases of femoral neck fractures in older population.

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