

Four Screws Diamond Configuration Fixation for Displaced, Comminuted Intracapsular Fracture Neck Femur in Young Adults

Abstract

Background: Four cannulated cancellous screws (CCS) in diamond configuration have been recommended by some authors for fixation of intracapsular neck of femur (ICNF) fracture with posterior comminution in adults. This is also supported by biomechanical studies. However, the clinical usefulness of this biomechanical advantage is not known. This study evaluates the outcomes of displaced, comminuted ICNF fracture in young adults managed by four CCS fixation in diamond configuration. **Materials and Methods:** 25 patients who met the inclusion criteria were operated during the study period. Four patients were lost to followup in the first 6 weeks postoperatively, and one patient died in first 6 months of followup unrelated to surgery. Thus, twenty patients were followed up for a mean period of 33.3 months (range 25–38 months). In all patients, fracture fixation was done with four CCS in diamond configuration. Union at fracture site and avascular necrosis (AVN) of femoral head was assessed on serial plain radiographs. Functional outcome was evaluated by Harris hip score. **Results:** Eighteen patients had union, two patients had nonunion, and two patients had AVN of femoral head. All the sixteen patients who had union without AVN had good or excellent functional outcome. **Conclusions:** The present study concludes that four CCS fixation in diamond configuration appears to be a reasonable choice of fixation for displaced fracture ICNF with comminution in young adults. However, further evaluation with better study design and larger patient population is required for definite conclusions.

Keywords: Avascular necrosis, cannulated cancellous screw fixation, diamond configuration, comminution, displaced, fracture neck femur, Gardens Grade III or IV

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Introduction

Comminution of the posterior aspect of the neck in displaced fracture intracapsular neck of femur (ICNF) is seen in about 35%–70% cases.^{1,2} Posterior comminution is an important cause of insecure fixation.^{1,2} The degree of comminution cannot be assessed easily because it is not always evident on initial radiographs. It is best demonstrated on the lateral view X-ray after reduction of fracture. In severely displaced, comminuted fractures even after reduction is achieved, it is difficult to maintain it by conventional methods of fixation, as the gap created due to posterior comminution closes and the proximal fragment angulates posteriorly as the cortex collapses.^{2,3} Thus, posterior comminution is a major cause of instability and subsequent nonunion.^{2,3}

There is broad consensus among orthopedic surgeons that fracture ICNF can be stabilized with three cannulated cancellous

screws (CCS).^{4,5} The use of a fourth screw has not shown to have a significant increase in mechanical advantage in most femoral neck fractures.⁶ However, Weinlein suggested that in the presence of significant posterior comminution, a fourth screw for internal fixation can be placed.⁵ Similarly in a biomechanical cadaveric study, Kauffman *et al.* demonstrated that fracture neck femur with posterior comminution stabilized with four screws had significantly more resistance to axial and anterior displacement than those fractures stabilized with three screws.⁷ However, the clinical usefulness of this biomechanical advantage is not known. Hence, the aim of this study was to evaluate the outcome of displaced, comminuted ICNF fracture in young adults managed by four CCS fixation in diamond configuration.

Materials and Methods

Twenty five young adults with displaced, comminuted fracture ICNF managed by

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Access this article online

Website: www.ijoonline.com

DOI:
10.4103/ortho.IJOrtho_333_17

Quick Response Code:



How to cite this article: Rajnish RK, Haq RU, Aggarwal AN, Verma N, Pandey R, Bhayana H. Four screws diamond configuration fixation for displaced, comminuted intracapsular fracture neck femur in young adults. *Indian J Orthop* 2019;53:70-6.

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four CCS fixation in diamond configuration between October 2013 and November 2014 were included in this prospective study. The first patient was recruited on October 10, 2013, and the last on November 16, 2014. All patients were followed up till December 2016. The inclusion criteria were: patients of either sex between the age of 18–55 years with Gardens grade III or IV ICNF fracture with comminution. Patients with Gardens Grade I or II fractures, basicervical fractures, fractures without comminution, polytrauma patients, ipsilateral fracture shaft femur, open injury, pathological fracture, on oral/injectable steroids, clinically detectable major illness and patients not willing to give consent, were excluded from the study.

The fracture was classified according to Garden Classification,⁸ Pauwels classification⁹ and anatomical classification.⁴ Comminution was documented on preoperative cross-table lateral view radiograph of affected hip, and on cross-table lateral view image taken under fluoroscope after reduction [Figure 1]. NCCT scan was done in 7 patients. This was done in patients where fracture patterns was not clear on plain radiographs. The ethical committee of our hospital approved the study plan, and informed consent was obtained from all patients before the operation.

Operative procedure

Under suitable regional anesthesia, the patients were taken for closed reduction on a fracture table. Reduction was done

under image intensifier control by applying gentle traction with the limb abducted to around 20° followed by internal rotation till the patella was internally rotated to 20°-30°.¹⁰ Garden's alignment index was used for assessment of the adequacy of reduction.¹¹

A straight skin incision of about 6 cm was made centering over the flare of the greater trochanter over the lateral aspect of thigh. Fascia lata was cut longitudinally in the line of skin incision. Vastus lateralis muscle was split along its fibers and retracted. The periosteum was elevated. The anteversion of the femoral neck was determined by placing a guide wire on the anterior aspect of femoral neck, and its position was confirmed under image intensifier. Under image intensifier guidance first guide wire was passed in the inferior quadrant. The guide wire was above the level of lesser trochanter within 3–5 mm of inferior cortex buttressing the inferior cortex of femoral neck. The position of the guide wire was checked in both anteroposterior (AP) and lateral views. It was inferiorly placed supporting the femoral neck in AP view and central in lateral view. After the inferior guide wire was placed, two more guide wires were inserted, proximal to the inferior wire one within 3–5 mm of posterior cortex and another within 3–5 mm of anterior cortex, keeping all wires parallel under image intensifier guidance. This made the standard apex distal triangle. The fourth guide wire was placed superiorly within 3–5 mm of superior cortex maintaining parallelism of all guide wires. Except for the first guide wire, the sequence

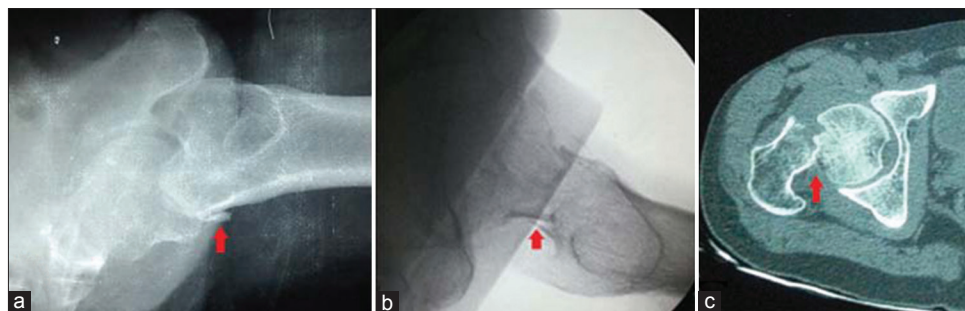


Figure 1: (a) Preoperative lateral view X-ray of fracture neck of femur, red arrow showing comminution, (b) postreduction fluoroscopic image of fracture neck femur lateral view, red arrow showing posterior comminution (c) preoperative NCCT scan of fracture neck of femur, red arrow showing comminution

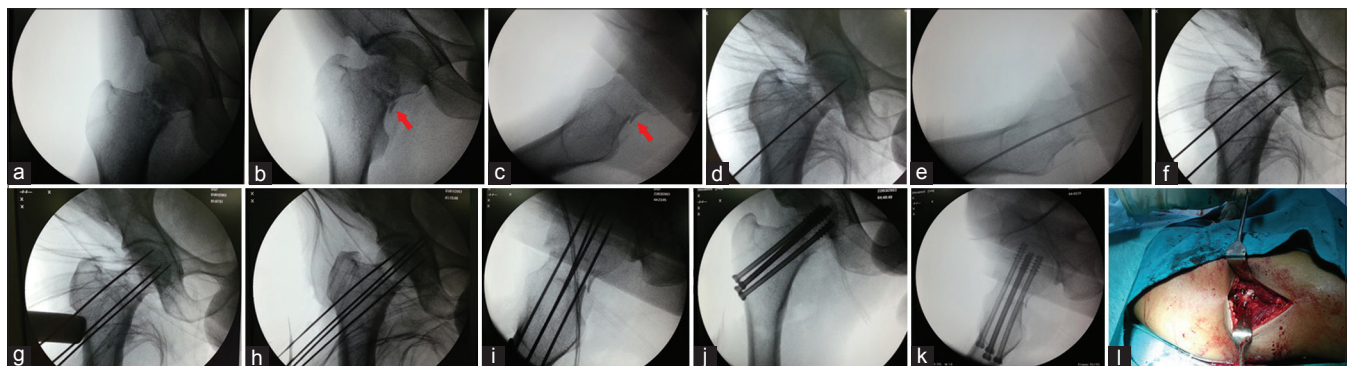


Figure 2: Serial fluoroscopic images (a) prereluction, (b and c) showing reduction under fluoroscope with red arrow showing comminution, (d-i) placement of guide wires, and (j and k) anteroposterior and lateral views after fixation with four CCS. Image (l) showing final clinical picture after fixation of fracture

of wire placement was changed if needed. All the guide wires were advanced in femoral neck and head to within 5 mm of subchondral bone. The length of each guide wire was measured for appropriate size of screws by direct measuring device of guide wires. Cannulated drill bit was used to drill over the guide wire and tapping was done with a cannulated tap. Appropriate size 16 mm partially threaded CCS of 7.0 mm were inserted over guide wires and guide wires were removed. The position of screws in 2 orthogonal views was confirmed. Final tightening of all the screws was done simultaneously one after other, after releasing the traction. Wound was closed in layers [Figures 2-3].

If two gentle attempts of closed reduction failed, an open reduction was performed. Open reduction was done in four patients using the anterolateral Watson Jones approach. Titanium implants were used in 3 patients while stainless steel implants were used in rest of the patients. All implants were from the same manufacturer (M/s Shakti Orthopaedics India Pvt. Ltd., Gurgaon, Haryana, India).

Knee range of motion was started on postoperative day one. Isometric quadriceps strengthening exercise and toe touch weight bearing with two crutch walking was allowed for first 3 months as tolerated. Full weight bearing with a walking aid was allowed thereafter once the bridging trabeculae across the fracture line appeared.

Patients were followed up clinically and radiologically at 2 weeks, and then every 6 weeks till union at fracture site occurred and thereafter at every 6 months. They were examined for surgical site infection, pain, hip range of motion and limb length discrepancy if any. Radiological assessment of the fracture was done by serial anteroposterior view in 15° internal rotation and lateral view taken at each followup.

We considered the fracture as united once fracture lines become indistinct or non appreciable and there was no

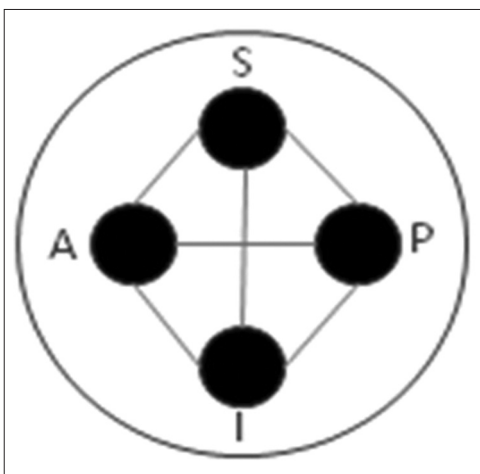


Figure 3: Superior (S) and inferior (I) screws are at equidistance from the line joining anterior (A) and posterior (P) screws making diamond configuration. Distance AP = 1.57 cm and SI = 1.86 cm

sclerosis at fracture margins. The function of the operated hip was evaluated by Harris hip score at the final followup.

Results

Four patients were lost to followup in the first 6 weeks' postoperatively, and one patient died in first 6 months of followup unrelated to surgery leaving twenty out of twenty-five patients who were followed up for a mean period of 33.3 months (range 25–38 months). There were 14 males and 6 females. The mean age of the patients was 38.5 years (range 18–55 years). Eleven patients had the fracture due to fall from height, eight patients had it following road traffic accident and one patient was a victim of physical assault. Twelve patients had Garden grade III and eight patients had Garden grade IV fracture. Three patients had subcapital and 17 patients had transcervical type of fracture. Fourteen patients had Pauwels type II and 6 had Pauwels type III fracture. Eighteen patients had posterior comminution while 2 patients had anterior comminution. The mean duration of injury to surgery was 9.4 days (range 1–19 days) [Figure 4].

Union was seen in 18 (90%) patients while two patients had nonunion [Figure 5]. Mean union time was 14 weeks (12–24 weeks). Out of the eighteen patients who had union two patients had avascular necrosis (AVN) of femoral head.

All the sixteen patients who had a union without AVN had good or excellent functional outcome. Their average Harris hip score at final followup was 94 (range 87–97). Out of the two patients who had nonunion, one patient with Garden grade IV fracture had open reduction at 14th day postinjury. At 16 months of followup, there was change in screw position, varus collapse of femoral head, and a visible fracture line [Figure 6]. However, the patient was able to walk without support, could squat, sit cross-legged, and had minimal pain at operated hip. He refused any further intervention and he is being kept in close followup. The other patient with nonunion had Garden grade III fracture and had intraarticular placement of one the screw which was revised with shorter screw on postoperative

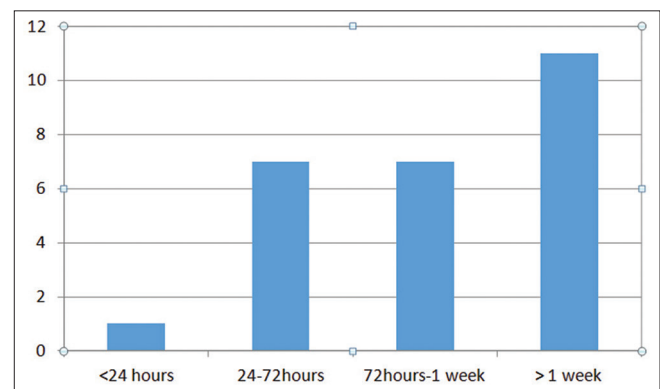


Figure 4: Bar diagram showing injury to surgery duration of all twenty patients



Figure 5: Preoperative anteroposterior radiograph (a) postoperative anteroposterior radiograph at postoperative day 1 (b), followup anteroposterior and lateral radiograph at 12 months (c and d), final followup anteroposterior and lateral radiographs at 32 months (e and f). Clinical images of same patient standing erect with weight bearing (g) sitting cross-legged, (h) squatting, (i) showing active straight leg raising (j)

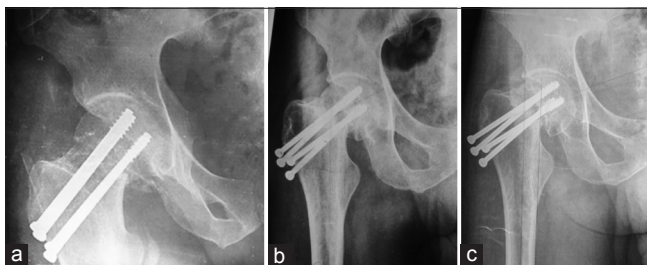


Figure 6: Anteroposterior radiograph of hip joint (a), postoperative 9 months' followup (b) and postoperative 16 months' followup (c) showing change in screw position, varus collapse and a visible fracture line

day two. The patient showed nonunion in early followup period. The patient had fair functional outcome despite an ununited fracture. He was able to walk with support with a limp, but was not able to squat and sit cross-legged and has mild pain at operated hip. This patient also declined any further surgical intervention, and is kept in close followup. No other patient underwent a second procedure for any intraoperative complications. Out of the two patients with AVN one had Garden grade IV fracture. The patient underwent closed reduction and fixation at 2nd day postinjury and developed AVN at 19 months of followup. The patient underwent total hip replacement. Other patient with AVN had Garden grade III fracture. Closed reduction and internal fixation were done at 12th day postinjury. The patient had radiological evidence of AVN at 30 months of followup but the patient had good functional outcome and could squat, sit cross legged and walk without support with mild pain. The patient was not willing for any intervention. No other complications were seen in postoperative followup.

In no case, the operating surgeon had to switch to using three CCS due to nonfeasibility of placement of four CCS due to inadequate width in the neck.

Discussion

A biomechanical cadaveric study has demonstrated that fracture neck femur with posterior comminution stabilized with four screws had significantly more resistance to axial and anterior displacement than those fractures stabilized with three screws.⁷ However, there are no studies to prove if this increased stability has any clinical benefit, hence the need for this study. In our opinion when one stands erect, it is the superior and inferior screws [Figure 7a and b], which acts as the beam to support the hip and neutralize the deforming forces across the fracture site. While in sitting position when hip joint is in flexion, the anterior and posterior screws support the hip and neutralize the deforming force across fracture site [Figure 7c and d]. Thus, four screws construct in diamond configuration provides stability during all positions of the hip movement.

There is paucity of literature on management of fracture ICNF with comminution. To best of our knowledge, there are only two studies in which posterior comminution has been considered,^{12,13} however, authors used techniques other than 4 CCS for fixation. Rawall *et al.* in a study of 27 patients of femoral neck fracture with posterior comminution fixed with three CCS found that there was nonunion in eight (29.6%) patients at one year of followup period.¹² Similarly, Zahid *et al.*¹³ who used two CCS and fibular strut graft for the fixation of femoral neck fracture with posterior comminution in 33 patients, found that there

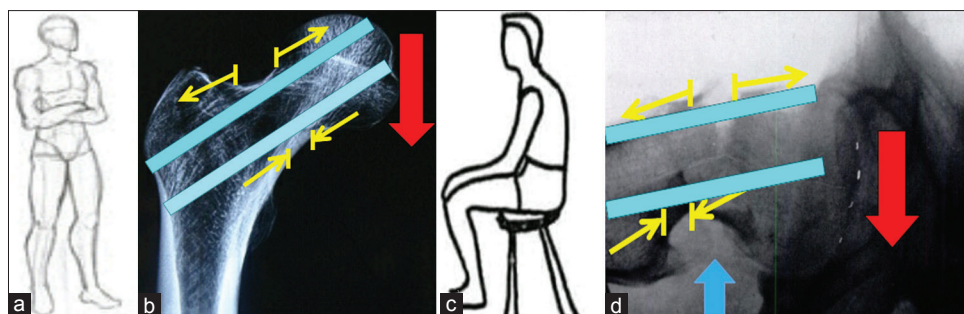


Figure 7: Images (a and b) deforming force acting at the hip joint across the fracture line in standing erect shown by red arrow, superior and inferior screws required to neutralize the deforming force, shown by thick blue line, (c and d) showing the deforming force acting at the hip joint across the fracture line in sitting with hip in flexion shown by red arrow, anterior and posterior screws required for neutralization of deforming force, shown by thick blue line. Blue arrow showing comminution

was nonunion in six (18%) patients at mean followup period of two years. Better result in terms of fracture union in our study (18/20; 90%) patients may be attributed to better fixation with adequate initial stability at fracture site provided by four CCS in diamond configuration, which may have prevented early loss of reduction compared to three CCS fixation, used by Rawall *et al.* and 2 CCS and fibular strut graft by Zahid *et al.*

In our study, two (10%) patients had AVN of femoral head as assessed by plain radiographs at mean followup of 33.3 months. Rawall *et al.* found AVN in six (22.2%) patients on bone scan while there was no evidence of AVN on plain radiographic assessment at one year of followup period.¹² They used bone scan in addition to plain X-ray for the evaluation of AVN which may be the reason for higher rate of AVN in their series. However, followup duration was shorter (1 year) than our study. Higher AVN rates in the current study when compared to study by Zahid *et al.* may be due to the fact that fibular graft acts as biological implant for neovascularization due to osteoinductive and osteoconductive potential compared to metallic implant used in our study as stated by the author. This may also be attributed to longer injury to surgery duration in the current study. The literature does suggest that occurrence of AVN is not in the control of surgeon.⁴

Functional outcome in our study was excellent or good in 16 patients at the final followup. One patient with AVN underwent total hip replacement. In contrast, Rawall *et al.*¹² found excellent functional outcome in nine patients, good functional outcome in nine patients, fair outcome in seven patients, and poor in two patients at one year of followup using a modified Harris hip score. While Zahid *et al.*¹³ found that functional outcome was good to excellent in 20 patients, fair in seven patients and poor in six patients as evaluated by Harris hip score. We believe that four screws in diamond configuration construct provide adequate stability at the fracture for union to occur which finally results in better average functional outcome. We also compared our union and AVN rates with other studies of fracture ICNF irrespective of whether comminution was present or not [Table 1]. The current study had comparable rate of nonunion and AVN.

Some surgeons are apprehensive of inserting four CCS in fracture ICNF, believing that there is not enough space in the femoral neck to do it, especially in our population where the average neck diameter is probably less than that of the Caucasians due to short stature. However, we did not encounter any difficulty intraoperatively in placing four CCS in femoral neck in any patient. The average distance between anterior and posterior screws was 1.57 cm and between superior and inferior screws were 1.86 cm [Figure 3]. A study by Pathrot *et al.*²⁴ concluded that the width of the femoral neck in Indian population on plain radiographs of the contralateral uninjured limb of patients with intertrochanteric or subtrochanteric fractures is 32.55 ± 3.14 mm. Assuming the cortex is 2 mm thick the inner diameter would be 28.55 mm. Assuming a circumferential bone bridge of 1 mm around a 7.0 mm screw would increase its effective diameter to 9.0 mm. The maximum number of 9.0 mm cylinders that can be placed in a tube with inner diameter of 28.55 mm is seven.²⁵ Therefore, the belief of some surgeons that there is not enough space in femoral neck for putting four CCS [Figure 8] is actually not true. However, there may be a small group of patients with very narrow necks where one may have to put three screws. Patwa *et al.* in a Bio-Geometric study concluded that it is not possible to put more than three screws in femoral neck in Indian population as the femoral neck does not have a uniform diameter but is a teardrop-shaped structure.²⁶ The problem of putting four CCS even if the femoral neck is teardrop shape may occur for four-quadrant peripheral fixation but not for a diamond configuration as done in the current study.

One of the limitations of our study is that 20% of the patients were lost to followup, which is considerably high. We excluded these patients from the final analysis rather than carrying forward their last observations using the “intention to treat” principle. As it is a case series and not a randomized control trial, we believe this methodology did not bias our results in any way. The other weakness of our study was the long delay between injury and surgery. This was mainly because of patients reporting late to the hospital

Table 1: Comparison of union and avascular necrosis rates of our study with other methods of fixation

Authors	Year	Number of patients	Type of fracture	Intervention	Rate of nonunion (%)	AVN of femoral head (%)	Followup period
Kofoed <i>et al.</i> ¹⁴	1982	17	Undisplaced and displaced	CRIF	24	41	2 years
Dedrick <i>et al.</i> ¹⁵	1986	25	Not defined	-	20	36	61 months
Gray and Parker ¹⁶	1994	58	Undisplaced and displaced	Different methods of fixation	7	10	586 days
Gautam <i>et al.</i> ¹⁷	1998	28	Displaced	Three CCS	4	12	32 months
Upadhyay <i>et al.</i> ¹⁸	2004	102	Displaced	Three CCS	17.4	16.3	2 years
Haidukewych <i>et al.</i> ¹⁹	2004	83	Undisplaced and displaced	Internal fixation	8	23	6.6 years
Gurusamy ²⁰	2005	395	Displaced fracture	Three CCS	38.7 (153)	-	100 days
Butt <i>et al.</i> ²¹	2008	52	Displaced	Three cannulated screws	9.6	13.5	40 months
Huang <i>et al.</i> ²²	2010	122	Displaced	Three CCS	18.9	17.2	55 months
Yang <i>et al.</i> ²³	2013	202	Displaced	Three screws	21.8	-	1 year
Present study	2016	20	Displaced fracture	4 CCS	10	10	33.3 months

AVN=Avascular necrosis, CRIF=Closed reduction internal fixation, CCS=Cannulated cancellous screw

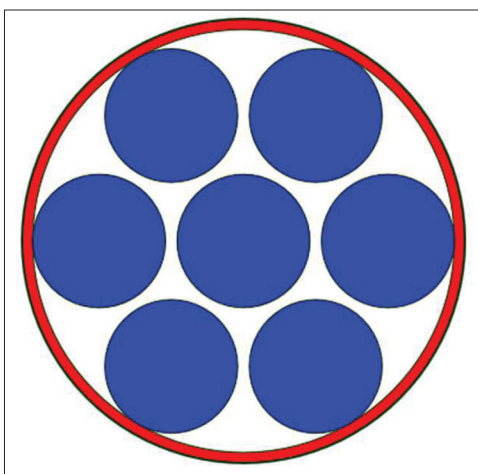


Figure 8: The maximum number of 9.00 mm cylinders that can be placed in a tube of inner diameter 28.55mm is seven

or being diagnosed with uncontrolled co-morbidities before being fit for surgery. This actually represents the more realistic situation about how hip fractures are managed in institutions where dedicated hip surgery protocols have not been established. The other weakness of the study is that there is no control group for comparison.

Thus, based on our results of excellent or good functional outcome and low rates of nonunion and AVN in fracture neck femur with comminution fixed with four CCS, we conclude that the use of four CCS in diamond configuration appears to be feasible treatment option in fracture ICNF with comminution. However, further evaluation is required with better study design and larger patient population for definite conclusions.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have

given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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