

Treatment of neglected femoral neck fracture

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ABSTRACT

Intra-capsular femoral neck fractures are seen commonly in elderly people following a low energy trauma. Femoral neck fracture has a devastating effect on the blood supply of the femoral head, which is directly proportional to the severity of trauma and displacement of the fracture. Various authors have described a wide array of options for treatment of neglected/nonunion (NU) femoral neck fracture. There is lack of consensus in general, regarding the best option. This Instructional course article is an analysis of available treatment options used for neglected femoral neck fracture in the literature and attempt to suggest treatment guides for neglected femoral neck fracture. We conducted the “Pubmed” search with the keywords “NU femoral neck fracture and/or neglected femoral neck fracture, muscle-pedicle bone graft in femoral neck fracture, fibular graft in femoral neck fracture and valgus osteotomy in femoral neck fracture.” A total of 203 print articles were obtained as the search result. Thirty three articles were included in the analysis and were categorized into four subgroups based on treatment options. (a) treated by muscle-pedicle bone grafting (MPBG), (b) closed/open reduction internal fixation and fibular grafting (c) open reduction and internal fixation with valgus osteotomy, (d) miscellaneous procedures. The data was pooled from all groups for mean neglect, the type of study (prospective or retrospective), classification used, procedure performed, mean followup available, outcome, complications, and reoperation if any. The outcome of neglected femoral neck fracture depends on the duration of neglect, as the changes occurring in the fracture area and fracture fragments decides the need and type of biological stimulus required for fracture union. In stage I and stage II (Sandhu’s staging) neglected femoral neck fracture osteosynthesis with open reduction and bone grafting with MPBG or Valgus Osteotomy achieves fracture union in almost 90% cases. However, in stage III with or without AVN, the results of osteosynthesis are poor and the choice of treatment is replacement arthroplasty (hemi or total).

Key words: Femoral neck, neglected, nonunion

MeSH terms: Femoral neck, neglected diseases, fractures ununited

INTRODUCTION

Intra-capsular femoral neck fractures are seen commonly in elderly people following a low energy trauma. 2-3% of all femoral neck fractures occurs in adults younger than 50 years and is often the result of high-energy trauma. Femoral neck fracture continues to be considered as an unsolved fracture in view of poor prognosis and variable outcome reported after different procedures.¹ In developing countries the fracture often remains

untreated as the patients do not seek treatment due to nonavailability of treatment facility or may be treated primarily by osteopaths or operated under suboptimal theatre conditions with poor quality implants. The problem gets compounded and the outcome deteriorates further in such situations.

Femoral neck fracture has a devastating effect on the blood supply of the femoral head, which is directly proportional to the severity of trauma and displacement of the fracture.² The intra-capsular hematoma is also implicated with development of avascular necrosis (AVN) of femoral head.² Femoral neck fractures in young adults are associated with higher incidences of osteonecrosis, with the rate reported in the literature from 12% to 86%. Early anatomical reduction and stable internal fixation restores the vascularity and reduces the incidence of AVN.³ Nonunion and AVN of the femoral head are the main complications following femoral neck fractures. The reasons for such complications include precarious vascularity, shearing forces at the fracture site, inadequate reduction and inadequate fixation.³ The nonunion (NU) is complicated by resorption at fracture ends leading to significant shortening of the femoral neck.

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Various authors have described a wide array of options for treatment of neglected/NU femoral neck fracture.⁴⁻³⁴ There is lack of consensus in general, regarding the best option. This instructional course article is an analysis of available treatment options used for neglected femoral neck fracture in the literature and an attempt to suggest treatment guidelines for neglected femoral neck fracture.

MATERIALS AND METHODS

We conducted a Pubmed search with the keywords “NU femoral neck fracture, neglected femoral neck fracture, muscle-pedicle bone graft in neglected femoral neck fracture, fibular graft in femoral neck fracture and valgus osteotomy in femoral neck fracture.” A total of 203 published papers were obtained as the search result. Forty eight papers considered fresh cases of femoral neck fracture, while 18 presented outcome of hemi/total hip arthroplasty as the treatment option in fresh and neglected cases, 4 were case reports, 9 were review articles or instructional course lectures, 8 were on pediatric femoral neck fracture, (71 were not related to the NU femoral neck fracture) and no abstract or full papers were available in 12 papers, hence were excluded from the analysis. The papers that dealt with fractures of the neck femur more than 3 weeks old in adults (prospective and retrospective) were chosen for this article. A total of 33 articles were considered. All these articles thereafter were categorized into four subgroups based on treatment options, (a) treated by muscle-pedicle bone grafting (MPBG), (b) closed/open reduction internal fixation and fibular grafting (c) open reduction and internal fixation with valgus osteotomy, (d) miscellaneous procedures. The data was pooled from all groups for mean neglect, the type of study (prospective or retrospective), classification used, procedure performed, mean followup available, outcome, complications, and reoperation if any.

RESULTS

Muscle pedicle bone graft (8 studies)

Six full papers and two abstract were analyzed.⁴⁻¹¹ Seven studies^{4-6,8-11} were prospective, and 1 was retrospective.⁷ These studies included 368 patients [Table 1]. The average age was 35.58 years ($n = 198$) in series where the mean age was described. In all studies, X-ray was the main investigating modality. None of the study used any particular classification system described for neglected or un-united femoral neck fracture. The mean neglect averaged at 6.45 months (range 3 weeks-9 months) in 166 cases (These are those cases of studies in which range were mention). The techniques used were Tensor fascia lata based muscle pedicle bone graft ($n = 48$), anterior trochanteric pedicle graft ($n = 3$) and quadratus femoris based graft ($n = 317$).

The average followup was at 49.15 months ($n = 156$), in remaining mean followup was not described. The average time to union was 8.1 months ($n = 135$). There were overall 16 NUs, 3 AVN and 13 varus malunion in 201 patients (16% complications) where results were described, whereas in 167 cases the complications were not described.

Open/closed reduction with fibular grafting (7 studies)

5 were prospective^{13-15,17,18} and 2 retrospective studies.^{12,16} The total number of patients were 406 [Table 2]. The mean neglect mentioned in 4 studies averaged at 20.48 weeks ($n = 119$). The average age of the patients was 35.7 years ($n = 138$). Radiograph was the principle investigation in all the studies. Sandhu *et al.* ($n = 236$)¹⁸ used a classification system proposed by the author himself for NU neck of femur. All the studies performed open or closed reduction and fixation with one or two fibular auto-grafts, however in the study by Elgafy *et al.*,¹² six patients underwent fibular allograft fixation along with cannulated cancellous screw (CCS). The average time to union was at 22.45 weeks ($n = 170$). The average followup was not known for two study, one study by Azam *et al.*¹⁶ reported ($n=28$) the minimum followup of 36 months. The average followup in rest of the four studies was 66.93 months ($n = 119$). Roshan and Ram¹⁷ ($n = 32$) did not report any complications. There were 33 NU and 11 AVN reported in 374 patients (11.3% complications).

Valgus osteotomy (11 studies)

The valgus osteotomy was performed below the level of the fracture site except in one study by Pingle²⁴ ($n = 29$), where the closing wedge osteotomy was performed at the level of fracture, and a wedge of bone was removed, with its apex at the nonunion site [Table 3]. The osteotomy entered the fracture, and the wedge of bone was grafted into the NU site. The mean neglect was 20 weeks ($n = 73$, mentioned in 3 studies).^{25,27,29} The average age of the patients was at 33.99 years ($n = 285$).^{19-21,25-29} The principle investigation done was X-ray in all these studies. None of the studies used any particular classification system for NU of femoral neck fractures. The mean followup was 52.38 months ($n = 293$). The mean time to union was 16.86 weeks (9 studies, $n = 138$).^{19-24,27-29} Complications in 3 studies ($n = 69$) were not reported.²²⁻²⁴ There were 22 NU and 21 AVN ($n = 285$) in remaining 8 Studies (15% complications).

Miscellaneous procedures

This group included 7 studies³⁰⁻³⁶ in which techniques other than that mentioned above or a combination of techniques was used [Table 4]. The study by Ayoub and Gad³² used the classification of Sandhu *et al.*¹⁸ (Type I, $n = 20$ and Type II, $n = 16$). Three studies ($n = 84$) reported outcome of bone grafting at the fracture site, with

Table 1: Data from studies on MPBG

Author	Type of study	Number of patient	Average age (years)	Technique	Follow-up (years)	Time to union	Mean neglect	Complications	Functional result
Bhuyan ⁵ (2012)	Prospective	48	32.9	ORIF+TFL MPBG±multiple drilling and cortico-cancellous bone grafting	4.4	Not mentioned	86 days	NU (n=3) AVN (n=2) Var (n=2)	HHS 19 E 22 G 5 F 2 P Not mentioned
Vallamshetia et al. ⁷ (2010)	Retrospective	42	34	ORIF+QF MPBG±cortico cancellous BG	Not mentioned	6 months	9 months	NU (n=6) Var (n=9) LLD (n=9)	Not mentioned
Gupta et al. ⁹ (2008)	Prospective	32	45	ORIF+QF MPBG	3.4	Not mentioned	>3 weeks (29)	NU (n=2) F. drop (n=2) scrotal sensory loss (n=1) Var (n=1) AVN (n=1) Var (n=1)	Salvatti and Wilson E15, G4 S4 P6 93 final average HHS
Gupta ⁸ (2007)		20	24	ORIF+QF MPBG	5.10	4.9 months	7.5 months	Not mentioned	Not mentioned
De and Balasubramaniam ¹⁰ (1991)	Prospective	3	Not mentioned	Anterior trochanteric muscle pedicle graft	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned
Baksi ⁶ (1986)	Prospective	56	42	ORIF with MPBG	2.14	3-6 months in 42 8-10 months in 7	6.3 months	NU (n=5)	Not mentioned
Meyers et al. ¹¹ (1973)		150	Not mentioned		Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned
Nair et al. ⁴ (2013)	Prospective	17	Not mentioned	QF	Not mentioned	8 months	Not mentioned	Not mentioned	Not mentioned

ORIF=Open reduction and internal fixation, MPBG=Muscle pedicle bone grafting, TFL=Tensor fascia lata, QF=Quadratus femoris, AVN=Avascular necrosis, NU=Nonunion, HHS=Harris hip score, LLD=Limb length discrepancy, Inv=Investigation, E=Excellent, G=Good, S=Satisfactory, F=Fair, P=Poor, Var=Varus, Fdrop=Foot drop

Table 2: Data on fibular graft

Fibular graft									
Author	Type of study	Number of patient	Average age (years)	Technique	Follow-up	Time to union	Mean neglect	Complications	Functional result
Elgafy et al. ¹² (2011)	Retrospective	19	46	Fibula Auto (n=13) Allo (n=6)	Not mentioned	4.8 months auto 13.3 months Allo	Not mentioned	NU (n=4) Auto NU (n=4) Allo	Not mentioned
LeCroy et al. ¹³ (2002)	Prospective	22	28.7	Free vascularized fibular grafting	84.7 months	9.9 months	18.3	NU (n=2)	HHS average 78.9
Xie et al. ¹⁴ (2012)		13	30.9	ORIF+free vascularized fibular grafting	51.2 months	4.8 months	6.7 months	Var (n=9)	HHS average 55.5
Azam et al. ¹⁶ (2009)	Retrospective	32 (28 followed)	37.8	CR/OR IF with 2 CCS and fibular strut graft	3 years Min.	5.2 months	16.4 weeks	NU (n=3) AVN (n=6) Var (n=4)	Anglen E 5 G 14 P 6
Roshan et al. ¹⁷ (2006)	Prospective	32	18-50	OR+2 CCS+1 free fibular graft	6.1 years	19.2 weeks	3-6 months		HHS 87.1 (mean)
Sandhu et al. ¹⁸ (2005)	Prospective	236	Not mentioned	CRIF+CCS+fibular graft	Not mentioned	Not mentioned	Not mentioned	NU (n=20)	Not mentioned
Nagi et al. ¹⁵ (1998)	Prospective	52	35.1	OR+CCS+free fib graft	58.8 months	16.7 weeks	5.1 months	NU (n=4) AVN (n=5) Var (n=11)	Not mentioned

ORIF=Open reduction and internal fixation, CRIF=Closed reduction internal fixation, CR=Close reduction, OR=Open reduction, IF=Internal fixation, CCS=Cannulated cancellous screw, AVN=Avascular necrosis, NU=Nonunion, HHS=Harris hip score, Auto=Autograft, Allo=Allograft, Var=Varus

Table 3: Data on valgus osteotomy

Valgus osteotomy									
Author	Type of study	Number of patients	Average age (years)	Technique	Follow-up	Time to union	Mean neglect	Complications	Functional result
Varghese et al. ²⁵ (2013)	Retrospective	40 (32 FU)	43	Valgus intertrochanteric osteotomy	5 years	Not mentioned	6 months	NU (n=3)	HHS 82 average
Bansal et al. ²⁶ (2013)	Prospective longitudinal observational study	30	35.4	Valgus osteotomy with double angle barrel plate	1-5 years	Not mentioned	>3 weeks	NU (n=2)	Askin Bryan index 11 E 15 G
Gavaskar et al. ²⁷ (2013)	Prospective longitudinal observational study	11	41	Sliding subtroch osteotomy+DHS	Not mentioned	10 weeks	6 months	Not mentioned	Oxford hip score
Kainth et al. ²⁸ (2011)		22	33	CR+valgus osteotomy for singh ind. >3 <3 + fibular. graft and no osteotomy	19 months	20 weeks	12 weeks	NU (n=1) AVN (n=2)	Askin Bryan E 2 G 17 P 3
Khan et al. ²⁰ (2009)	Prospective	16	36.4	Valgus osteotomy+ double angle barrel plate+DHS	19 months	14.7 weeks	>3 weeks	Implant cut out (n=2)	Not mentioned
Magu et al. ²¹ (2009)	Retrospective	48	48.1	Modified Pauwels' intertrochanteric osteotomy	6.1 years	Not mentioned	Not mentioned	NU (n=4) AVN (n=2)	Not mentioned
Stringari et al. ²² (2005)	Prospective	20	Not mentioned	Valgus osteotomy+double angle blade plate	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned
Kalra et al. ²³ (2001)		20	Not mentioned	Valgus osteotomy	30 months	Not mentioned	Not mentioned	Not mentioned	Not mentioned
Pingle ²⁴ (2014)	Prospective	29	Not mentioned	Valgus osteotomy	66 months	6 months	Not mentioned	Not mentioned	Not mentioned
Raaymakers et al. ²⁸ (2008)	Prospective	66	49.5	Valgus osteotomy	110 months	Not mentioned	Not mentioned	NU (n=8) AVN (n=13)	Not mentioned
Gupta et al. ¹⁹ (2014)	Prospective	60	35	Valgus osteotomy	42 months	3.9 months	Not mentioned	NU (n=2) AVN (n=4)	Not mentioned

DHS=Dynamic hip screw, AVN=Avascular necrosis, NU=Nonunion, HHS=Harris hip score, CR=Close reduction, E=Excellent, G=Good, P=Poor

Table 4: Data on combined procedures

Author	Type of study	Number of patient	Average age (years)	Technique	Follow-up	Time to union	Mean neglect	Complications	Functional result
Huang ³³ (1986)	Not mentioned	16	16-43	CRIF/ORIF/augment osteo/BG	2-8 years	Not mentioned	Not mentioned	AVN (n=4)	Not mentioned
Ayoub and Gad ³² (2013)	Not mentioned	36	26.8	ORIF with CCS+BG±bone marrow	25.3 months	19.6 weeks	44.6 days	NU (n=2) AVN (n=2) Var (n=4)	Not mentioned
Sen et al. ³⁵ (2012)	Prospective	22	Not mentioned	Angle blade plate+fibular grafting	3.2 years	Not mentioned	11.2 months	AVN (n=1) NU (n=1)	Not mentioned
Garg ³¹ (2011)	Prospective	32	38	Neck reconstruction (AIIMS box technique)	Minimum of 10 years	16 weeks	Not mentioned	AVN (n=1)	Not mentioned
Chen and He ³⁶ (2008)	Prospective	28	37.6	Iliac crest graft+vascular pedicles from lateral circumflex iliac	35.8 months	4-8 months	8.6 months	NU (n=3), AVN (n=7)	mentioned HHS: 49.6 (mean)
Kapoor et al. ³⁰ (2012)	Not mentioned	23	Not mentioned	ORIF with DHS+Valgus osteotomy+fibular grafting	2-13 years	Not mentioned	Not mentioned	AVN (n=4)	Not mentioned
Gadegone et al. ³⁴ (2013)	Prospective	41	45.41	Valgus osteotomy+ fibular strut grafting	32.5 months	16.82 weeks	14 weeks	NU (n=2)	Not mentioned

ORIF=Open reduction and internal fixation, CRIF=Cannulated cancellous screw, BG=Bone graft, DHS=Dynamic hip screw, HHS=Harris hip score, AVN=Avascular necrosis, NU=Nonunion

average age at 32.4 years.^{31,32,36} One of these studies is described as the AIIMS Box technique³¹ (n = 32). The average time to union in this study was 16 weeks, where simple bone grafting at the fracture site led to the union by 19.6 weeks (n = 36). The mean neglect mentioned only by Ayoub *et al.*³² was at 44.6 days. In all there were 7 AVNs, 2 NU and 4 Varus Malunion (n = 84, 15.5%). The valgus osteotomy and fibular autografting were combined in n = 86 patients (3 studies).^{30,34,35} The average age was 45.41 years (n = 41) in one study. No particular classification system was used by any of the studies. The average followup was at 35.25 months (n = 63). The average time to union was mentioned only in the study by Gadegone *et al.* as 16.82 weeks (n = 41).³⁴ The mean neglect was at 7.35 months (n = 63). There were 5 cases of AVN and 3 NU amongst the total of 86 patients (9.25%). Chen and He³⁶ reported 28 patients in whom Iliac crest corticocancellous grafting was done along with vascular pedicles from lateral circumflex iliac artery. The mean neglect of the patients was 8.6 months, and mean followup of 35.8 months. The average time to union was 4-8 months, and there were 3 incidents of NU and 7 incidents of AVN (n = 28).

DISCUSSION

Pathoanatomy

The medial circumflex femoral artery (MCFA), lateral circumflex femoral artery (LCFA) and the obturator artery form the main blood supply to femoral head.¹ The obturator artery supplies the femoral head through the ligamentum teres. The LCFA gives rise to the inferior metaphyseal artery and supplies infero-anterior femoral head. The largest contributor to the femoral head, especially the superolateral aspect of the femoral head is the MCFA. The lateral epiphyseal artery complex arises from the MCFA and courses along the posterosuperior aspect of the femoral neck before supplying the femoral head. These terminal branches supplying the femoral head are intra-capsular. Fracture displacement disrupts the terminal branches to the femoral head and leads to development of osteonecrosis.³⁷⁻³⁹

Classification

Pauwel's and Garden's classification systems are the two most commonly used radiological classification system for fresh femoral neck fractures. These classifications describe for fresh fractures and cannot be used reliably to predict the outcome in cases of NU femoral neck fracture.

The changes that occur at the fracture site once the fracture remains untreated are (a) absorption of femoral neck (b) fracture surfaces get smoothed (c) the fracture gap is increased and (d) the head of the femur can develop

AVN. These changes occur in variable severity depending on the length of neglect. Pauwel and Garden's classification do not consider these variables and hence are unsuitable to be used for classifying neglected femoral neck fracture.

X-ray of pelvis including both hip joints in the identical position should be taken to classify neglected femoral neck fracture. The length of the proximal fragment is measured from upper margin of fovea centralis to the midpoint of fracture margin. Sometimes the absorption of the proximal fragment is more marked in the center than the periphery giving it the shape of a cup or moon. This may not be clearly seen on routine anteroposterior X-ray of the hip and can be better appreciated on computed tomography (CT) scan or magnetic resonance imaging (MRI). AVN of the head of the femur may be seen earlier on MRI than on plain X-ray of the hip. Sandhu⁴⁰ described a classification system for NU/neglected femoral neck fracture incorporating these changes at various stages. Based on these changes, he classified the neglected femoral neck fracture into 3 types (described as 3 stages).

The radiological findings are:



Stage I

- a. Fracture surfaces are still irregular (irregular or jagged)
- b. The size of the proximal fragment is 2.5 cm or more
- c. Gap between the fragments is 1 cm or less
- d. Head of the femur is viable with no sign of AVN on X-ray or MRI.

The presence of good size femoral head fragment allows good hold of implant while performing internal fixation, and very little resorption of neck and absence of AVN promotes fracture healing.

Stage II

- a. Fracture surfaces are smooth and sclerosed
- b. The size of the proximal fragment is 2.5 cm or more
- c. The gap between the fragments is more than 1 cm but <2.5 cm
- d. The head of the femur is viable.

If either sclerosed and smoothened proximal end or a fracture gap more than 1 cm is observed it can be labeled as stage II. The freshening of fracture surfaces by drilling or curettage while performing open reduction is indicated along with bone grafting. The proximal fragment is big enough for good and stable purchase by implant, hence suitable for osteosynthesis.

Stage III

- a. Fracture surfaces are smoothened out
- b. The size of the proximal fragment is <2.5 cm
- c. The gap between the fragments is more than 2.5 cm

- d. The head of the femur shows signs of AVN. The presence of any of the latter three, that is, proximal fragment <2.5 cm, (inadequate for good hold of implant) or fracture gap more than 2.5 cm or head of femur has AVN are placed in stage III marks the fracture unsuitable for osteosynthesis.

Neglected femoral neck fracture presents with shortening, severe external rotation of the lower extremity, upward displacement of the trochanter, with or without soft tissue contracture. Head and neck would have undergone variable degree of absorption. Plain X-rays are adequate to make a clinical diagnosis and stage the neglected femoral neck fracture. CT scan may be useful to see the bony appearance of stippled area and bony sclerosis, trabecular resorption, microfracture and subchondral collapse and presence of AVN. Bone scan may be indicative of AVN, but MRI is most sensitive modality to diagnose AVN.⁴¹

Treatment

The goal of treatment in neglected fracture NOF is to achieve a painless, mobile and stable hip.²⁹ The treatment depends on the age and physical status of the patient, duration of NU, viability and sphericity of the femoral head, amount of resorption of the femoral neck and potential limb length inequality. Various options of management are described in the literature, all with variable outcomes in various series. They are grouped as

- (a) Osteosynthesis with or without vascularized or nonvascularized bone grafting
- (b) Osteotomy, displacement or angulation type
- (c) Osteosynthesis with muscle pedicle bone grafting
- (d) Replacement (hemiarthroplasty or THR).

(a) Closed/open reduction, internal fixation and single or double fibular grafting

In this procedure closed or open reduction and CCS fixation of the fracture is performed after freshening the fracture surfaces. Some of the authors¹²⁻¹⁸ used open reduction of fracture with freshening of fracture surfaces and placed cancellous autograft alongwith fibula. Fibula being cortical bone provides mechanical strength besides stimulating the union and getting incorporated as a biological graft. Once the graft is revascularized, the osteoblasts stimulated by bone morphogenic protein replace the resorbed bone. If this bone is appropriately stressed, the graft acquires sufficient strength to handle the load.¹⁶ Nonvascularized fibular strut graft along with cancellous screws provides a dependable and technically less demanding alternative procedure for neglected femoral neck fractures in young adults. Vascularized fibular graft are reported to give superior result; however, it consists of microvascular anastomosis that is technically more demanding. Leung and Shen¹² obtained 100% union and satisfactory clinicoradiographic

result at 5-7 years followup using vascularized iliac bone graft augmented by screw fixation. One or two guidewires are placed to guide a tunnel for fibula. First a tunnel is created by triple reamer and later one or two fibulae are placed (with fixation done by two CCS at least). The use of nonvascularized fibular strut graft is technically less demanding. In the present search thirty-three NUs were reported out of 374 cases while AVN was reported in 11 cases (3%), with an overall complication rate of 11.3%.

(b) Valgus intertrochanteric osteotomy

McMurray Osteotomy used to be commonly described and performed procedure.⁴⁴ It is a displacement osteotomy. In general one-third of the neglected fracture NOFs unite while in the remaining it provided an armchair effect, improving the ambulation. The displacement osteotomy (like McMurray osteotomy) makes future hip replacement difficult, hence are no longer performed. None of the authors performed McMurray's Osteotomy in the available search.

Pauwel's V-Y osteotomy is an inter-trochanteric osteotomy which starts at the base of the greater trochanter and goes to the point just above the lesser trochanter. A suitable wedge of about 20°-30° is excised from the lateral half or 2/3rd of femur, thus giving the shape of VY to the osteotomy.¹⁹⁻²² The distal fragment is abducted to close the gap created by excision of the wedge and is fixed with dynamic hip screw or 135° blade plate or double angle blade plate. Hence, the fracture line which was vertical gets converted into horizontal and the shearing forces get converted into compressive forces.

Other osteotomy is a simple lateral closed wedge valgus osteotomy (done just at or below the level of lesser trochanter) where a wedge of bone is excised and the osteotomy is closed. This may be combined with open reduction, freshening of fracture surfaces and bone grafting. Valgus inter-trochanteric osteotomy is an alternative line of treatment for these patients. Pauwels and Müller advised Y-shaped wedge-closing – wedge-opening osteotomy to treat pseudo-arthritis of the femoral neck. The Y-shaped osteotomy reduces the area of contact of the osteotomy surfaces. On the other hand, simple V-shaped wedge removing osteotomy provides broad osteotomy surfaces that ensure good bony contact on closure of the osteotomy and lateralization of the femoral shaft. Valgus inter-trochanteric osteotomy results in rotation of the upper segment of the femur in a clockwise manner for the left hip and counterclockwise for the right hip. The osteotomy line becomes obliquely situated, running downwards and laterally, and its lateral end is displaced distally, resulting in lengthening. Lengthening is usually desirable to compensate for the shortening that is present in these cases. The femoral

shaft is now displaced medially and becomes vertically oriented after the osteotomy. Osteotomy fixation with a double-angled plate will maintain this deformed position. On the other hand, fixation with a single-angled blade plate will pull the femoral shaft laterally and distally to the plate along the slope of the obliquely situated osteotomy line.²¹ This will result in correction of the medialisation of the femoral shaft and also restore the normal inclination of the femur to the sagittal plane. These effects have a positive influence on the knee joint in preventing the valgus strain and overloading. In this analysis 22 out of 285 cases who underwent valgus osteotomy remained un-united, while 21 out of 285 cases developed AVN. The combination of various procedures has also been described with success.³⁰⁻³⁶ In a single article by Pingle J *et al.*²⁴ Lateral closing wedge osteotomy based laterally was performed approximately 4 cm below and directly opposite the nonunion site and parallel to the pins into the nonunion site. The proximal cut of osteotomy was made parallel to the proximal pins and the distal cut of the osteotomy was angled to get the desired wedge laterally.

(c) Muscle pedicle bone graft

The fracture surfaces are freshened, and the fracture is accurately reduced and fixed with cancellous screws. A piece of bone about 2.5-3.0 cm long and about 1.0-1.5 cm wide is harvested. The graft is placed across the femoral neck fracture and the head. The graft may be secured with a screw. Various muscle-pedicle based grafts are described. Posterior approach is used for Quadratus Femoris based MPBG. Tensor Fascia Lata and Gluteus medius based MPBG is done in lateral or supine position by lateral or anterolateral approach.⁵⁻¹⁰

Myoperiosteal grafting for inducing osteogenesis is reported for where the Quadratus Femoris pedicle is lifted with a strip of periosteum from neck and is placed across the fracture. The author reported 20 neglected fracture NOF with a mean delay of 7.5 months (range 2-18 months). 100% fracture union was reported in a mean of 4.9 months and with a mean followup of 70 months (range 14-144 months). The preoperative AVN was seen in 7 cases and did not progress in 6. Delayed collapse and flattening of the femoral head occurred in one. The author also opined that anatomical reduction is not mandatory for fracture union, provided its vascularity has been restored.⁸ A muscle-pedicle bone graft seems to accelerate the union of fresh intra-capsular fractures.^{11,42} Meyers and Harvey¹¹ reported the results of their technique for delayed union. 9 years later Baksi⁴³ reported encouraging results with muscle-pedicle bone graft in the treatment of posttraumatic AVN of the femoral head whether the fracture was united or not.⁴³ The placement of the muscle-pedicle bone graft behind the femoral head and neck served several purposes: it acted as a strut across

the posterior cortical defect; it prevented posterior tilt of the femoral head; and it acted as a viable vascular inlay graft encouraging osteosynthesis and revascularization of the femoral head. Originally Baksi had described fixing the graft with pins and threads, however in later series screws were used for fixation. In the present analysis, the fracture united in 92% cases with 3 out of 201 reporting AVN and 13 out of 201 developing malunion.

(d) Replacement arthroplasty

Hemireplacement can be performed when the acetabulum is normal, and age of the patient is more than 75 years, and life expectancy is about 5 years.^{1,42} This operation is of short duration. The hemiarthroplasty can become painful after sometime due to loosening or acetabular erosions. Hemiarthroplasty can be performed with a cemented modular stem so that modular bipolar can be later converted to THA. Total hip arthroplasty is indicated in younger patients of 55 years or less. More in stage III neglected fracture NOF or when osteosynthesis and osteotomy has failed to achieve fracture union. It allows early rehabilitation and lasts longer than hemiarthroplasty. After THA the patient is not allowed to squat and sit crosslegged. Dislocation (1-5%), infection (1%), periprosthetic fracture (1%) and aseptic loosening are other complications.

The problem with the data available in the literature is manifold: (a) The choice of procedure is not correlated with the length of neglect (b) no classification system is used as a result, each series has clubbed cases of all duration of neglect, that is, from 3 weeks to 11 months and reported the outcome. The mechanical and biological disturbance at fracture site will be different with length of neglect. Hence, it is appropriate to use classification proposed by Sandhu *et al.* we propose a guideline of treatment depending on the duration of neglect.

Neglected fracture NOF less than 4 weeks

It is usually staged I by Sandhu's classification. At this stage closed or open reduction and internal fixation is the preferred line of management. One may consider adding bone grafting at NU site if open reduction is contemplated. The fracture with vertical fracture line (Pauwel's Type II or III) would require a valgization osteotomy. The implant chosen may be CCSs. However, if valgization osteotomy is undertaken then nail plate assembly is the intended construct. The rate of fixation failure and NU are reported as 10%. It is advisable to follow the patient on a long term basis for the risk of developing AVN and secondary osteoarthritis. Poor reduction and improper placement of the screws is a major factor for failure of union at NU site.

Neglected fracture NOF between 4 weeks and 3 months

Generally, these NU are either stage II or sometimes stage I, The choice of treatment is open reduction and internal fixation with bone grafting (vascularized or nonvascularised) or valgization osteotomy. The extreme valgus position after osteotomy should be avoided. The angulation osteotomy is to be fixed with angle hip screws and side plates. Good results are also reported with open reduction and internal fixation with compression screws and free fibular graft. However complications like fibular graft breakage and screw penetration into joint do occur.

Neglected fracture NOF between 3 and 6 months

Generally, these NUs are stage II, however could be stage III also. In all these cases where the head fragment is vascular, open reduction, freshening of fracture surfaces, bone grafting at NU site and internal fixation by CCS and MPBG could be a good strategy. Which muscle to choose for MPBG and the consequent approach could be the surgeon's choice.

Hip arthrodesis may be considered for very young patients. However, the procedure is not preferred by patient or surgeons. In an established case with AVN in stage III one may have to resort to hemiarthroplasty or THR.

Neglected fracture NOF more than 6 months

These fractures are stage III, hence prosthetic replacement (hemi or total) is generally preferred. However, if still in stage II with a vascular femoral head, a hip preserving surgery may also be considered.

CONCLUSION

The outcome of neglected femoral neck fracture depends on the duration of neglect, as the changes occurring in the fracture area and fracture fragments decides the quality of biological materials required for fracture union. In Sandhu's stage I and stage II neglected femoral neck fracture osteosynthesis with open reduction and bone grafting with MPBG or Valgus Osteotomy achieves fracture union in almost 90% cases. However, in stage III with or without AVN, the results of osteosynthesis are poor and the choice of treatment is replacement arthroplasty (hemi or total).

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