

Nonvascularized fibular grafting in nonunion of femoral neck fracture

A systematic review

Sujit Kumar Tripathy, Ramesh Kumar Sen¹, Tarun Goyal²

ABSTRACT

Nonunion of femoral neck fractures following primary fixation and neglected femoral neck fracture in young adults is a challenging task. Every effort should be directed toward hip joint salvage in these patients. Among different available options of hip salvage, nonvascularized fibular graft (NVFG) osteosynthesis is simple, easy to perform, and a successful technique. In this review, the available literature on NVFG in neglected and nonunion femoral neck fractures has been analyzed. After review of 15 articles on NVFG, the average nonunion rate was estimated to be 7.86% (range 0–31%). Six articles that evaluated the preoperative and postoperative osteonecrosis reported improvement in 50% patients. The clinical and/or functional outcome was good to excellent in 56–96% patients following fibular osteosynthesis. Few complications such as coxa vara deformity, limb shortening, and intraarticular penetration of the graft or hardware have been reported. However, there are minimal donor site morbidities such as mild ankle pain, transient loss of toe flexors and extensors and transient lateral popliteal nerve palsy.

Key words: Femoral neck fracture, fibular graft, hip salvage, neglected fracture, nonunion, osteosynthesis

MeSH terms: Femoral neck fractures, fibula, osteosynthesis, fracture, grafting, bone

INTRODUCTION

Management of neglected and nonunion of femoral neck fracture is a challenging task.¹⁻⁴ There is no exact definition of neglected femoral neck fracture in the literature. Some studies report more than 3 weeks of delay as neglected, while others take 6 weeks as the time limit. However, definition of nonunion is relatively clear. Zuckerman defined it as a lack of radiographic evidence of union 6 months after the fracture.⁵ The patient usually presents with pain on weight bearing after 3 months of fixation. Radiological evidence of nonunion becomes apparent within 1 year.⁶⁻⁹ The incidence of nonunion as

reported in literature varies between 10% and 30%.^{4,10} The choice of treatment in such scenario depends on the age, the activity level, the duration of injury, the extent of displacement, and osteoporosis.⁴ This fracture is common in the elderly population in Western countries, but young individuals equally succumb to this injury in developing countries because of high incidence of road traffic accident.¹⁰ While nonunion following primary fixation in the young adults is a worrisome problem for the patients and the surgeon both throughout the world, many patients in the developing or underdeveloped countries do not seek medical treatment for months and remain neglected.

The treatment of nonunion or neglected femoral neck fracture in the elderly patients is a prosthetic replacement, and there is no controversy in such management.^{4,10-13} However, there is no firm guideline to deal with femur neck fracture nonunion or neglected cases in the young individuals. Many

Department of Orthopaedics, All India Institute of Medical Sciences, Bhubaneswar, Odisha, ¹Department of Orthopaedics, Fortis Hospital, Mohali, Punjab, ²Department of Orthopaedics, All India Institute of Medical Sciences, Rishikesh, Uttarakhand, India

Address for correspondence: Dr. Sujit Kumar Tripathy, Department of Orthopaedics, All India Institute of Medical Sciences, Bhubaneswar - 751 019, Odisha, India. E-mail: sujitortho@yahoo.co.in

Access this article online	
Quick Response Code:	Website: www.ijoonline.com
	DOI: 10.4103/0019-5413.185587

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Tripathy SK, Sen RK, Goyal T. Nonvascularized fibular grafting in nonunion of femoral neck fracture: A systematic review. Indian J Orthop 2016;50:345-51.

hip preserving procedures are adopted in these young individuals. The procedures are either a proximal femoral osteotomy or bone grafting (muscle pedicle graft, vascularized or nonvascularized fibular graft [NVFG]) or a combination of osteotomy and bone grafting.¹⁰⁻¹³ Proximal femoral osteotomy usually causes shortening, limping, and restriction of range of motion with the potential risk of nonunion at the osteotomy site.¹³ The vascularized bone grafting is technically more challenging and need expertise, but NVFG is simple and technically easier to perform.¹³

NVFG for femoral neck fracture was first used by Henderson in 1940.¹⁴ Subsequently, Inclan and Patrick also reported a favorable outcome with the use of NVFG in fracture neck of the femur.^{15,16} “One cancellous screw and a fibular graft” was popularized by Nagi *et al.* in 1981 and subsequently, it was routinely used for neglected femoral neck fracture.¹⁷ In this review, the success rate, outcome, and complications of NVFG in neglected and nonunion of femoral neck fracture will be appraised.

MATERIALS AND METHODS

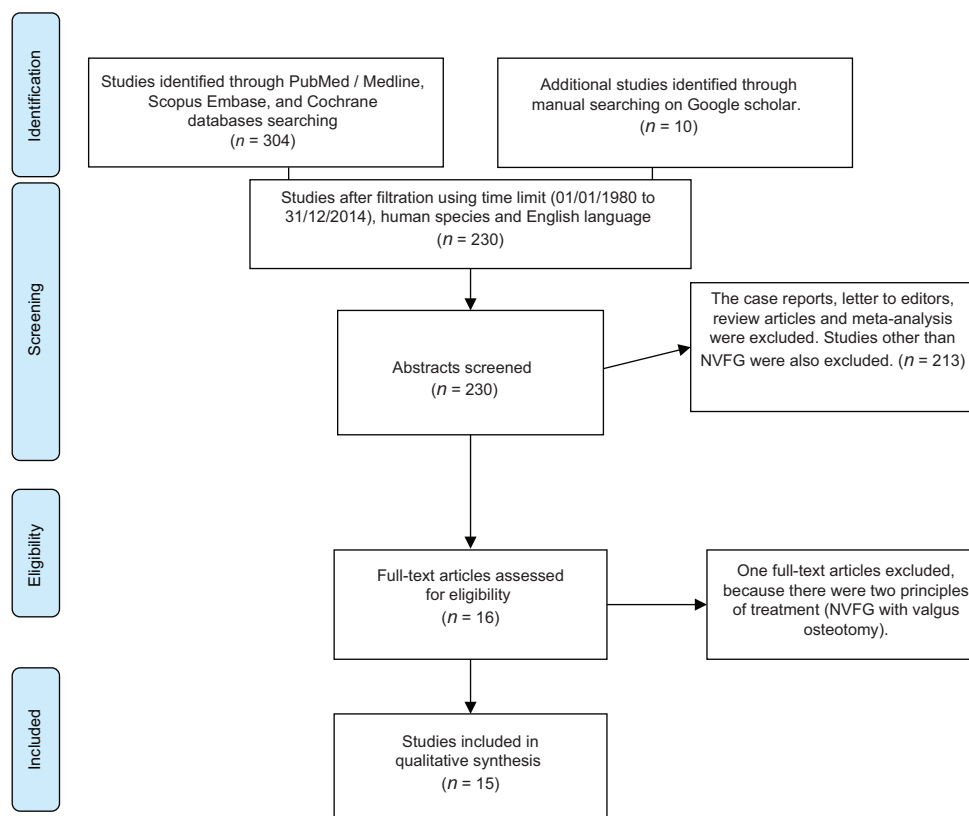
The PubMed/Medline, Scopus, Embase, and Cochrane databases were searched using keywords “nonunion femoral neck fracture,” “neglected femoral neck fracture,” and “fibular graft” to retrieve articles evaluating the outcome

of nonvascularized fibular graft in neglected and nonunion femoral neck fracture [Flow Chart 1]. A total of 304 articles were retrieved. After filtration, we could find 230 articles on human species published between January 01, 1980, and December 31, 2014, in English language. The case reports, letter to editors, review articles, and meta-analysis were excluded from this review. The abstract of the remaining articles was read and only those articles that evaluate the outcome of nonvascularized fibular graft in neglected and nonunion of femoral neck fracture were included for review. The references of these articles were also hand searched for any missing article. From 16 articles, one article¹⁸ on combined valgus osteotomy and fibular grafting were excluded as there were two principles of femoral neck fracture management. All total 15 articles were included in this review [Flow Chart 1].^{17,19-32}

RESULTS

Indications of fibular graft

All articles except by Dooley and Hooper²⁰ used NVFG in young adults below 60 years of age for neglected and nonunion of femoral neck fracture fixation. The definition of neglected femoral neck fracture varies in these articles. Nine articles reported more than 3 weeks of delay as neglected,^{17,23,24,26-30,32} whereas remaining articles mentioned more than 6 weeks as the definition of neglected fracture.^{19,25,31} However, the definition of



Flow Chart 1: PRISMA flow chart

nonunion is quite clear.²⁰⁻²² No evidence of progressive healing on anteroposterior and lateral radiographs and disabling hip pain within 6 months of primary fixation was considered as nonunion. Sen *et al.* had 16 nonunion after cannulated cancellous screw fixation and 6 nonunions after dynamic screw fixation, whereas Elgafy *et al.* reported eight nonunions after cannulated cancellous screw fixation, seven nonunions after dynamic screw fixation, and two after initial conservative treatment. Dooley and Hooper did not find an obvious cause of nonunions in all of their cases, but they could identify four nonunions because of inability to recognize the original fracture and ten nonunions were because of poor reduction or inadequate fixation. As per the Sandhu *et al.*, Grade I femoral neck nonunion (proximal fragment >2.5 cm, irregular fracture margin, fracture gap of <1 cm, and viable femoral head) has union rate of 100% followed by 89% in Grade II (proximal fragment >2.5 cm, smooth fracture margin, fracture gap between 1 and 2.5 cm, and viable femoral head) and 33% in Grade III (proximal fragment <2.5 cm, smooth fracture margin, fracture gap between >2.5 cm, and osteonecrotic femoral head) after NVFG osteosynthesis. Partial resorption of neck and presence of osteonecrosis in the femoral head are not a contraindication and it may show improvement after fibular osteosynthesis.^{17,19,21,25,26} Thus, neglected or nonunion femoral neck fracture (whether displaced or undisplaced) with proximal fragment more than 2.5 cm and fracture gap of <2.5 cm can be effectively treated with NVFG osteosynthesis.

Methods of reduction, supplementary fixation, and rehabilitation

Closed reduction or open reduction

Two articles by Nagi *et al.* reported open reduction (OR)^{17,19} and another seven reported closed reduction (CR) of the fracture site.^{22,23,28-32} Five articles reported CR where possible and OR when CR failed.^{20,21,24-26} The authors supporting OR assert that by opening the nonunion site, the interposed fibrous tissue between the fracture fragments can be removed. Moreover, the fracture ends can be freshened, and the neck-shaft angle can be adjusted. The other group of authors who claim that there is no need to open the fracture site believes that the fibular graft acts as a biological augmentation and stimulate union in the interposed fibrous tissue that gets converted to osseous tissue. By not opening the fracture site, it preserves the blood supply of the femoral head.¹¹ The best approach seems to be intermediate between these two. An initial CR (traction in 45° flexion and then slight abduction followed by extension and internal rotation to 30–45° to bring the limb parallel to the trunk) should be attempted on a traction table.^{23,24,28-32} When CR fails (in grossly displaced fracture with neck resorption), OR through Watson–Jones anterolateral approach must be performed.^{21,24-26}

Nail, screw, or angle fixed device

Thirteen of fifteen articles reported use of cancellous screws (preferably cannulated) as the supplementary fixation.^{17,20,22-32} Dooley and Hooper used nail or plate as the supplementary fixation. Angle fixed device was reported in our own previous article.²¹ We believed that numerous complications such as graft slippage and fibular graft fracture that have been reported with the use cancellous screw were because of excessive force exerted on the graft and not offloaded by the screws. Angled blade plate (ABP) provides better stability because of its rectangular shape and resists more torsional and shearing forces.²¹ However, placement of ABP is technically more challenging. After this review, it is fairly apparent that a fibular graft with cannulated screws is an optimal fixation for neglected and nonunion cases of femoral neck fracture. This is technically simple and can be performed in most of the center.

One screw or multiple screws

Except Nagi *et al.*^{17,19} all authors recommended placement of two or three screws (6.5 mm or 7 mm cannulated cancellous screw) along with the fibular graft. The authors believe that multiple screw fixation allows early rehabilitation of the patients in the postoperative period. While Nagi *et al.*^{17,19} recommended hip spica cast for more than 6 weeks in their patients because of inadequate stability by one supplementary screw, remaining all authors²⁰⁻³¹ allowed early postoperative partial weight bearing in their patients because of better stability. Thus, additional support with two or more cannulated screws is desirable in NVFG osteosynthesis.

One graft or dual graft

Most of the articles reviewed used only one fibular graft for osteosynthesis [Figure 1].^{17,19-23,25-29,31} However, three articles^{24,30,32} reported about the dual fibular graft fixation. Sandhu *et al.*³² used one cancellous screw and a double fibular graft in 86.3% patients and two cancellous screws with one free fibular graft in 13.7%. They noted union in all of their patients with single fibular graft who were of Grade I nonunion as per Sandhu *et al.* In double fibular graft group, they noted 100% union in Grade I, 89% in Grade II, and 33% in Grade III. Pal *et al.*²⁴ used two fibular grafts with one screw for those patients who had a longer delay and greater resorption of the neck and/or posterior comminution of the femoral neck. For other neglected patients, they used only one graft and two screws. But nothing could be concluded from this article as it was not a comparative study rather the authors themselves divided the patients into these two groups of treatment and just reported the outcome combinedly. However, they noted a longer time for union in some of their patients who had excessive resorption of neck (treated with dual fibular graft). Similarly the report of Jaiswal *et al.*,³⁰ who divided the patients into two treatment groups (dual fibular graft and dual graft + one screw), also could not provide



Figure 1: X-ray left hip joint anteroposterior view showing (a) A 30-year-old female with 6-month-old femoral neck fracture; (b) the fracture has united after nonvascularized fibular graft osteosynthesis (c and d) After 13 years the hip joint is still preserved with good functional outcome (Courtesy: Professor Nagi)

extra information about the advantage of dual grafting. As per the current evidence, one fibular graft and two supplementary screws are adequate.

Rehabilitation

Except by Nagi *et al.*^{17,19} remaining all authors adopted an early rehabilitation. Nagi *et al.*^{17,19} used hip spica cast for 6 weeks because of one supplementary screw in their patients and hence the fixation was inadequate. Remaining all authors allowed immediate postoperative nonweight bearing walking on crutches for 6–8 weeks and then partial weight bearing. Complete weight bearing was restricted until radiological evidence of union was noticed.

Clinical outcome

Nonunion

On cumulative evaluation of the patients in the reviewed articles, the average nonunion rate after NVFG is 7.86% [range: 0–31%, Table 1].^{17,19-32} The nonunion rate in 12 of 15 studies was <10%.

Osteonecrosis

All except two studies^{22,27} have mentioned the number patients who developed osteonecrosis or who had

Table 1: Studies evaluating the outcome of fibular osteosynthesis in neglected and nonunion of femoral neck fracture

Study	Total patients	Preoperative osteonecrosis	Method of fixation	Mean followup (months)	Nonunion (%)	Osteonecrosis (%)
Dooley and Hooper (1982)	26	-	CR/OR + nail-plate + fibular graft±osteotomy	108	2 (7.69)	3 (11.53)
Nagi <i>et al.</i> (1986)	16	4	ORIF + NVFG + 1 CS	29	0	0
Nagi <i>et al.</i> (1998)	40	8	ORIF + NVFG + 1 CS	59	2 (5)	5 (12.5)
Mishra <i>et al.</i> (1998)	15	-	ORIF + NVFG + Asnis screw	-	1 (6.67)	-
Sandhu <i>et al.</i> (2005)	168	9	CR + NVFG (145 patients with one screw and dual fibular graft, 23 patients with two screws and one fibular graft)	63	20 (11.90)	6 (3.57)
Roshan and Ram (2006)	32	0	CR/OR + NVFG (central) + 2 CS	73	3 (9.3)	0
Goyal <i>et al.</i> (2006)	15	-	CR + NVFG + 2 CS	24.4	0	0
Gupta <i>et al.</i> (2006)	25	-	CR + NVFG + 3 CS	24	0	1 (4)
Singh <i>et al.</i> (2006)	25	-	CR + NVFG + 2 CS	>24	1 (4)	5 (20)
Azam <i>et al.</i> (2009)	28	-	CR/OR + NVFG + 2-3 CS	54	3 (10.71)	6 (21.42)
Kainth <i>et al.</i> (2011)	14	0 (based on radiograph)	CR + NVFG + 2 CS	19	0	1 (7.14)
Elgafy <i>et al.</i> (2011)	13	-	ORIF + NVFG + 2-3 CS	-	4 (30.76)	-
Sen <i>et al.</i> (2012)	22	5	CR/OR + NVFG + ABP±1 screw	38	1 (4.54)	1 (4.54)
Jaiswal <i>et al.</i> (2013)	26	-	CR + NVFG (A: 8 dual fibular graft + B: 18 dual fibular graft with one screw)	6	2 (7.69) (1 in Group A and 1 in Group B)	2 (7.69) (1 in Group A and 1 in Group B)
Pal <i>et al.</i> (2014)	72	-	CR/OR + NVFG (dual fibular graft + 1 CS: 24, one fibular graft + 2 CS: 48)	36	4 (5.55)	3 (4.12)
Total	547				43 (7.86)	

CR=Closed reduction, OR=Open reduction, SP=Smith-Peterson, NVFG=Nonvascularized fibular grafting, CS=Cancellous screw, VFG=Vascularized fibular grafting, ABP=Angled blade plate

progression of osteonecrosis. The incidence of postoperative osteonecrosis varies between 0% and 21%.^{17,19-21,23-26,28-32} Six studies^{17,19,21,23,25,32} where the preoperative and postoperative osteonecrosis status are mentioned clearly indicate that there is an improvement in osteonecrosis after fibular osteosynthesis. A total of 26 patients (total avascular necrosis in these six articles) had osteonecrosis in the preoperative period and only 13 patients remained osteonecrotic in the postoperative period [improvement in 50% of patients, Table 1].

Hip scores

There was no uniformity in the evaluation of hip function or functional outcome. Various scores were used by the authors. The clinical and/or functional outcome was good to excellent in 56–96% of patients following fibular osteosynthesis [Figure 1 and Table 2].^{17,19,20-32}

Complications

Apart from nonunion and osteonecrosis, most common complications after fibular osteosynthesis are coxa vara

Table 2: Functional outcome and complications of fibular osteosynthesis in neglected and nonunion of femoral neck fracture

Study	Total patients	Functional outcome	Complications
Dooley and Hooper (1982)	26	-	Apart from 3 AVN, one had discomfort over greater trochanter, one had resorption of neck, one had inadequate reduction with poor placement of nail, one had nail protrusion, one fibular graft fracture, and one nonunion of osteotomy site No donor site morbidity
Nagi <i>et al.</i> (1986)	16	-	No serious complications. Three had coxa vara (children)
Nagi <i>et al.</i> (1998)	40	28 (70%) had good to excellent outcome as per Nagi's score	Five femoral head collapse, 11 coxa vara, four fibular graft fracture, leg length discrepancy 2.9 cm, six patients had screw penetration, and three had fibular graft penetration into the joint, two superficial infection
Mishra <i>et al.</i> (1998)	25	Fairly satisfactory function	-
Sandhu <i>et al.</i> (2005)	168	Range of movements regained in 148 (88.09%) patients in whom union of fracture was achieved: flexion 100-120°, abduction and adduction 20-45°, and rotation 20-45°. There was shortening of 0.5-1.5 cm in 18 patients. All 148 (88.09%) patients can squat, and 124 (83.78%) can sit in a cross-legged position. 143 (85.11%) patients remained clinically asymptomatic with normal preinjury activity	Osteonecrosis in six, inadequate length and improper placement of the graft in seven, fracture of the graft caused by early weight bearing in six, and deep infection in one. One patient had late collapse of the head of femur and four patients had radiologic signs of osteoarthritis. Morbidity at the donor site included temporary weakness of the extensor hallucis longus in eight patients and permanent in two patients
Roshan and Ram (2006)	32	23 (88.5%) of 26 patients had good to excellent outcome as per HHS	Three superficial infections, two had stiffness of knee and/or ankle, average leg length discrepancy 2.3 cm
Goyal <i>et al.</i> (2006)	15	11 (73.33%) of 15 patients had good outcome as per Larson's method of functional evaluation	Limb shortening six patients, superficial infection two patients, and one patient had intra-articular graft with screw cut out
Gupta <i>et al.</i> (2006)	25	24 (96%) of 25 patients had full range of hip movement and were able to resume routine activities	Transient lateral popliteal nerve palsy in one patient
Singh <i>et al.</i> (2006)	25	-	Restriction of movement in five patients who had osteonecrosis, knee and hip joint stiffness (two patients) and shortening-1" in four patients
Azam <i>et al.</i> (2009)	28	19 (76%) of 25 patients had good to excellent outcome as per modified Anglen criteria	Three superficial infection, seven minor complications such as mild ache, ankle swelling, some weakness of long flexors and extensors
Kainth <i>et al.</i> (2011)	14	Cannot be commented from the article. Seems to be satisfactory	One fibular graft slippage, one limb length discrepancy, and one superficial infection
Elgafy <i>et al.</i> (2011)	17	-	Two patients had persistent ankle pain after fibular graft harvest
Sen <i>et al.</i> (2012)	22	14 (63.6%) patients had good to excellent outcome as per Nagi's score	Transient loss of extensor hallucis longus power in three patients
Jaiswal <i>et al.</i> (2013)	26	62.5% and 55.6% of patients in Groups A and B, respectively, had good to excellent outcome as per Larson scoring system	One graft fracture, 37.5% and 27.8% of patients in Groups A and B had limb shortening of 0.5-1 cm
Pal <i>et al.</i> (2014)	72	50 (69.4%) patients had good to excellent outcome as per HHS	-

HHS=Harris Hip Score, AVN=Avascular necrosis

deformity, limb shortening, and intraarticular penetration of the graft or hardware.^{17,19,21-32} Very few cases of graft fracture and slippage have been reported.^{20,23-28,32} Contrary to it, donor site morbidity has not been reported so commonly. Few articles have reported mild ankle pain, transient loss of toe flexors and extensors, and transient lateral popliteal nerve palsy [Table 2].^{21,26,29}

DISCUSSION

Fibular osteosynthesis in neglected femoral neck fracture was popularized by Nagi *et al.*¹⁷ They used one cancellous screw and a fibular graft in their patients and reported union in all of them. They acknowledge that fibular osteosynthesis not only promotes union, it also improves the osteonecrosis in the femoral head. They advocated that mechanical fixation by various devices depends upon the physical pressure exerted by the nail and the bone. Normal vascular bones start resorption around the implant because of the physical load and hence it starts loosening leading to nonunion. However, the fibular graft provides biological fixation by beginning to fuse with the parent bone at the end of 3–4 weeks and thus implant loosening does not occur.

The hip salvage concept in nonunion or neglected cases of fracture neck femur is of two types: (1) Techniques to improve the mechanical environment around the fracture site and (2) techniques to improve the biological environment at the nonunion site by bone grafting.^{3,4,33,34} The exact indication of fibular graft in the nonunion or neglected condition has not been elucidated. From the review, we conclude that NVFG is a suitable option for displaced/nondisplaced femoral neck fracture nonunion with a proximal fragment of size larger than 2.5 cm with or without femoral neck resorption and osteonecrosis.^{3,4,10-13,21-32} A concomitant proximal femoral valgus osteotomy with fibular graft may be indicated in femoral neck fracture nonunion with varus hip.^{10,11}

Fibula being cortical bone provides mechanical strength to the fixation besides stimulating union. The incorporation of fibular graft with the surrounding bone gives biological fixation. Once the graft is revascularized, the osteoblasts stimulated by bone morphogenic protein replace the resorbed bone of the femoral neck and subchondral region. If this bone is appropriately stressed, the graft acquires sufficient strength to handle the observed forces.^{3,4,10-13,17}

From this review, it is quite evident that “one fibular graft and two cancellous screws” are optimal for fixation of neglected and nonunion cases. An early rehabilitation with crutch walking can be initiated immediately after surgery and complete weight bearing can be restricted till union at the fracture site. The success rate of NVFG is impressive

with nonunion rate <10%. Besides that, there is usually an improvement in osteonecrosis in about 50% patients. There are few complications and minimal donor site morbidity after autogenous NVFG fixation. The coxa vara deformity and leg length discrepancy that have been reported after NVFG is because of preoperative varus alignment/varus malreduction during surgery. Even in varus hip, fibular graft osteosynthesis promotes union; however, residual coxa vara and limb shortening persists. In such cases, combined valgus osteotomy and fibular graft can provide a better outcome.

To conclude, in patients younger than 60 years of age with neglected femoral neck fracture or nonunion, all efforts should be directed toward hip salvage. NVFG osteosynthesis has encouraging results in such instances. It is technically less demanding, simple, and can be performed in almost all centers where image intensifier is available.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Arbab S, Ud Din S. Osteosynthesis of intracapsular fracture neck of femur with cancellous screw and fibular graft. *J Postgrad Med Inst* 1991;5:64-9.
2. Huang CH. Treatment of neglected femoral neck fractures in young adults. *Clin Orthop Relat Res* 1986;206:117-26.
3. Haidukewych GJ. Salvage of failed treatment of femoral neck fractures. *Instr Course Lect* 2009;58:83-90.
4. Pauyo T, Drager J, Albers A, Harvey EJ. Management of femoral neck fractures in the young patient: A critical analysis review. *World J Orthop* 2014;5:204-17.
5. Zuckerman JD. *Comprehensive Care of Orthopaedic Injuries in the Elderly*. Baltimore: Urban & Schwarzenberg; 1990. p. 23-111.
6. Arnold WD, Lyden JP, Minkoff J. Treatment of intracapsular fractures of the femoral neck. With special reference to percutaneous Knowles pinning. *J Bone Joint Surg Am* 1974;56:254-62.
7. Banks HH. Factors influencing the results in fractures of the femoral neck. *J Bone Joint Surg* 1962;44A: 931-64.
8. Banks HH. Nonunion in fractures of the femoral neck. *Orthop Clin North Am* 1974;5:865-85.
9. Chapman MW, Stehr JH, Eberle CF, Bloom MH, Bovill EG Jr. Treatment of intracapsular hip fractures by the Deyerle method. A comparative review of one hundred and nineteen cases. *J Bone Joint Surg Am* 1975;57:735-44.
10. Estrada LS, Volgas DA, Stannard JP, Alonso JE. Fixation failure in femoral neck fractures. *Clin Orthop Relat Res* 2002;399:110-8.
11. Jain AK, Mukunth R, Srivastava A. Treatment of neglected femoral neck fracture. *Indian J Orthop* 2015;49:17-27.

12. Raaymakers EL, Marti RK. Nonunion of the femoral neck: Possibilities and limitations of the various treatment modalities. *Indian J Orthop* 2008;42:13-21.
13. Roshan A, Ram S. The neglected femoral neck fracture in young adults: Review of a challenging problem. *Clin Med Res* 2008;6:33-9.
14. Henderson MS. Ununited fracture of the neck of the femur treated by the aid of bone graft. *J Bone Joint Surg Am* 1940;22:91-106.
15. Inclan A. Late complications in fracture of the neck of the femur treated by nailing, bone grafting or both. *J Int Coll Surg* 1946;9:36-50.
16. Patrick J. Intracapsular fractures of the femur treated with a combined Smith-Petersen nail and fibular graft. *J Bone Joint Surg Am* 1949;31A: 67-80.
17. Nagi ON, Gautam VK, Marya SK. Treatment of femoral neck fractures with a cancellous screw and fibular graft. *J Bone Joint Surg Br* 1986;68:387-91.
18. Gadegone WM, Ramteke AA, Lokhande V, Salphade Y. Valgus intertrochanteric osteotomy and fibular strut graft in the management of neglected femoral neck fracture. *Injury* 2013;44:763-8.
19. Nagi ON, Dhillon MS, Goni VG. Open reduction, internal fixation and fibular autografting for neglected fracture of the femoral neck. *J Bone Joint Surg Br* 1998;80:798-804.
20. Dooley BJ, Hooper J. Fibular bone grafting for nonunion of fracture of the neck of the femur. *Aust N Z J Surg* 1982;52:134-40.
21. Sen RK, Tripathy SK, Goyal T, Aggarwal S, Tahasildar N, Singh D, *et al.* Osteosynthesis of femoral-neck nonunion with angle blade plate and autogenous fibular graft. *Int Orthop* 2012;36:827-32.
22. Elgafy H, Ebraheim NA, Bach HG. Revision internal fixation and nonvascular fibular graft for femoral neck nonunion. *J Trauma* 2011;70:169-73.
23. Kainth GS, Yuvarajan P, Maini L, Kumar V. Neglected femoral neck fractures in adults. *J Orthop Surg (Hong Kong)* 2011;19:13-7.
24. Pal CP, Kumar B, Dinkar KS, Singh P, Kumar H, Goyal RK. Fixation with cancellous screws and fibular strut grafts for neglected femoral neck fractures. *J Orthop Surg (Hong Kong)* 2014;22:181-5.
25. Roshan A, Ram S. Early return to function in young adults with neglected femoral neck fractures. *Clin Orthop Relat Res* 2006;447:152-7.
26. Azam MQ, Iraqi A, Sherwani M, Sabir AB, Abbas M, Asif N. Free fibular strut graft in neglected femoral neck fractures in adult. *Indian J Orthop* 2009;43:62-6.
27. Mishra D. Femoral neck fracture open reduction Asnis screw fixation and fibular grafting. *Indian J Orthop* 1998;32:32-5.
28. Goyal RK, Chandra H, Pruthi KK, Nirvikalp. Fibular grafting with cannulated hip screw fixation in late femoral neck fracture in young adults. *Indian J Orthop* 2006;40:94-6.
29. Gupta DK, Agarwal P. Fibular osteosynthesis in neglected femoral neck fractures. *Indian J Orthop* 2006;40:97-9.
30. Jaiswal A, Pruthi KK, Goyal RK, Pathak V, Habib M, Tanwar YS, *et al.* Evaluation of osteosynthesis with dual fibular bone grafting for neglected femoral neck fractures. *J Clin Orthop Trauma* 2013;4:58-69.
31. Singh D, Sharma CS, Bansal M, Meena DS, Asat RP, Joshi N. Ununited fracture neck of femur treated with closed reduction and internal fixation with cancellous screw and fibular strut graft. *Indian J Orthop* 2006;40:90-3.
32. Sandhu HS, Sandhu PS, Kapoor A. Neglected fractured neck of the femur: A predictive classification and treatment by osteosynthesis. *Clin Orthop Relat Res* 2005;431:14-20.
33. Tripathy SK, Sen RK, Goyal T. Reply to comment on Sen *et al.* Osteosynthesis of femoral-neck nonunion with angled blade plate and autogenous fibular graft. *Int Orthop* 2012;36:1321-2.
34. Tripathy SK, Goyal T, Sen RK. Revision internal fixation and nonvascular fibular graft for femoral neck nonunion. *J Trauma* 2011;71:270-1.