

## Role of autologous non-vascularised intramedullary fibular strut graft in humeral shaft nonunions following failed plating



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### ARTICLE INFO

#### Article history:

Received 21 October 2016  
Accepted 15 December 2016  
Available online 22 December 2016

#### Keywords:

Nonunion humerus  
Failed internal fixation  
Fibular graft  
Plate osteosynthesis  
Humeral shaft fracture

### ABSTRACT

**Background:** Non-union humeral shaft fractures are seen frequently in clinical practice at about 2–10% in conservative management and 30% in surgically operated patients. Osteosynthesis using dynamic compression plate (DCP), intramedullary nailing, locking compression plate (LCP), Ilizarov technique along with bone grafting have been reported previously. In cases of prior failed plate-screw osteosynthesis the resultant osteopenia, cortical defect, bone loss, scalloping around screws and metallosis, make the management of non-union more complicated. Fibular graft as an intramedullary strut is useful in these conditions by increasing screw purchase, union and mechanical stability. This study is a retrospective and prospective follow up of revision plating along with autologous non-vascularised intramedullary fibular strut graft (ANVFG) for humeral non-unions following failed plate osteosynthesis.

**Materials and methods:** Seventy eight cases of nonunion humeral shaft fractures were managed in our institute between 2008 and 2015. Of these, 57 cases were failed plate osteosynthesis, in which 15 cases were infected and 42 cases were noninfected. Out of the 78 cases, bone grafting was done in 55 cases. Fibular strut graft was used in 22 patients, of which 4 cases were of primary nonunion with osteoporotic bone. Applying the exclusion criteria of infection and inclusion criteria of failed plate osteosynthesis managed with revision plating using either LCP or DCP and ANVFG, 17 cases were studied. The mean age of the patients was 40.11 yrs (range: 26–57 yrs). The mean duration of non-union was 4.43 yrs (range: 0.5–14 yrs). The mean follow-up period was 33.41 months (range: 12–94 months). The average length of fibula was 10.7 cm (range: 6–15 cm). Main outcome measurements included bony union by radiographic assessment and pre- and postoperative functional evaluation using the DASH (Disabilities of the Arm, Shoulder and Hand) score. Results: Sixteen out of 17 fractures united following revision plating and fibular strut grafting. Average time taken for union was 3.5 months (range: 3–5 months). Complications included one each of implant failure with bending, transient radial nerve palsy and transient ulnar nerve palsy. No case had infection, graft site morbidity or peroneal nerve palsy. Functional assessment by DASH score improved from 59.14 (range: 43.6–73.21) preoperatively to 23.39 (range: 8.03–34.2) postoperatively ( $p = 0.0003$ ). Conclusion: The results of our study indicate that revision plating along with ANVFG is a reliable option in humeral diaphyseal non-unions with failed plate-screw osteosynthesis providing adequate screw purchase, mechanical stability and high chances of union with good functional outcome.

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### 1. Introduction

Humeral shaft fractures are relatively common injuries accounting for 5–8% of all fractures in human body and 14% of all fractures of humerus.<sup>1</sup> Historically, fractures of humerus have

been associated with high incidence of non-union. The advent of bracing and operative stabilization techniques led to significant decline in non-union rate.<sup>2</sup> Both conservative and surgical treatment result in healing. Conservatively managed humeral shaft fractures present with non-union rates of 2–10%, with most of the cases resulting from proximal third fractures or those with a proximal butterfly fragment.<sup>3</sup> In a review by Volgas et al., surgically managed fractures fared even worse with non-union rate as high as 30%.<sup>4</sup>

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Most of the non-union humeral shaft fractures can be managed successfully by conventional methods such as Dynamic Compression Plate (DCP) or Locking Compression Plate (LCP) fixation, intramedullary nailing, Ilizarov technique and bone grafting. These therapeutic options alone or in combination can achieve bony union in 82–95% of patients.<sup>5</sup> In multi-operated cases extensive bone loss due to previous implant, scalloping around screws, metallosis, osteopenia, nonviable intermediate butterfly fragments and instability pose a challenge for the surgical management along with risk factors such as alcoholism, diabetes mellitus, smoking, obesity and osteoporosis.<sup>3,6</sup> The use of fibular graft as an intramedullary strut in humeral nonunions was originally described by Wright et al. in a clinical and biomechanical study.<sup>7</sup>

The purpose of this study is to assess the role of autologous nonvascularized intramedullary fibular strut graft (ANVFG) in non-union diaphyseal humeral fractures following failed plate-screw osteosynthesis.

**2. Materials and methods**

**2.1. Study design**

A retrospective and prospective study was conducted after obtaining the Institutional Ethical Committee approval from our

Institute. Seventy eight cases of nonunion humeral shaft fractures were managed at our institute between 2008 and 2015. Of these, 57 cases were failed plate osteosynthesis, in which 15 cases were infected nonunion managed with Ilizarov method and 42 cases were non-infected managed with revision plating either with or without bone graft. Out of the 78 cases, either iliac crest or fibular bone graft was used in 55 cases. Fibular strut graft was used in 22 patients, of which 4 cases were of primary nonunion with osteoporotic bone. Applying the *exclusion criteria* of infection, pathological fractures, primary non-union, and revision cases managed with or without iliac crest bone graft alone and *inclusion criteria* of failed plate osteosynthesis managed with revision plating and ANVFG, we were left with 17 cases for the study (Table 1).

**2.2. Demographic data**

There were 14 male and 3 female patients. The mean age was 40.11 yrs (range: 26–57 yrs). 9 patients had right side and 8 patients had left side involvement. Type of non-union was classified according to Weber and Cech classification.<sup>8</sup> Fourteen patients had atrophic type of non-union and 3 patients had comminuted type of avascular non-union. One patient had non-union at proximal third-middle third junction, 10 patients had

**Table 1**  
Patient data.

S/NO	Age (yrs)	Sex	Side	Site	Duration of Nonunion (months)	No. of Prior Surgeries	Type of Nonunion	Risk factors	Approach
1	48	M	Rt	D/3rd	6	1	comminuted type	nil	posterior
2	33	M	Lt	M/3rd	8	1	atrophic type	nil	posterior
3	38	M	Rt	M/3rd	60	2	atrophic type	nil	posterior
4	48	M	Lt	M/3rd	48	1	atrophic type	Hepatitis B, Hepatitis C	posterior
5	28	M	Lt	M/3rd	12	1	atrophic type	epilepsy, on anti-epileptics	posterior
6	42	M	Rt	D/3rd	6	1	atrophic type	smoking- 10yrs	posterior
7	50	M	Lt	M/3rd	48	2	atrophic type	Hypertension	anterolateral
8	27	M	Lt	M/3rd	8	1	comminuted type	nil	anterolateral
9	57	F	Rt	M/3rd	144	1	atrophic type	Diabetes Mellitus, Hepatitis B	posterior
10	53	M	Lt	M/3rd	48	1	atrophic type	Diabetes Mellitus	anterolateral
11	30	M	Rt	M/3rd-D/3rd	48	1	atrophic type	nil	anterolateral
12	26	M	Lt	D/3rd	24	1	atrophic type	nil	posterior
13	45	F	Lt	M/3rd-D/3rd	72	1	comminuted type	nil	anterolateral
14	50	F	Rt	M/3rd	60	1	atrophic type	Hypertension	posterior
15	36	M	Rt	M/3rd	168	1	atrophic type	nil	anterolateral
16	36	M	Rt	D/3rd	24	2	atrophic type	Smoking-20yrs	anterolateral
17	35	M	Rt	P/3-M/3rd	120	1	atrophic type	Smoking	anterolateral

S/No	Age (yrs)	Sex	Implant	Fibula	Iliac Crest	Post Operative Complications	Union (months)	Duration of Followup (months)	Pre Op DASH Score	DASH Score at Final Followup
1	48	M	DCP	10 cm	–	nil	3	94	73.21	8.03
2	33	M	DCP	8 cm	–	nil	3	69	44.4	12.5
3	38	M	DCP	12 cm	–	nil	4	59	43.6	21.9
4	48	M	DCP	14 cm	–	nil	4	46	46.29	32.4
5	28	M	DCP	8 cm	–	nil	3	36	58.3	12.96
6	42	M	DCP	6 cm	–	nil	3	36	47.32	15.17
7	50	M	DCP	8 cm	–	nil	3	31	61.11	28.7
8	27	M	DCP	10 cm	–	implant failure – bending of plate	nil	30	48.1	29.6
9	57	F	DCP	13 cm	–	nil	4	25	66.4	34.2
10	53	M	DCP	14 cm	+	nil	4	23	59.2	31.48
11	30	M	DCP	15 cm	+	iatrogenic fracture during implant removal	4	22	61.6	14.28
12	26	M	LCP	15 cm	+	ulnar nerve palsy recovered in due course of time	5	21	58.3	19.6
13	45	F	DCP	8 cm	–	wrist drop recovered by 3 months	3	18	69.25	33.3
14	50	F	DCP	10 cm	–	nil	3	17	60.7	24.1
15	36	M	LCP	15 cm	–	nil	4	15	66.6	30.5
16	36	M	DCP	7 cm	+	Nil	3	14	68.75	21.4
17	35	M	PHILOS	10 cm	–	Nil	3	12	72.31	27.67

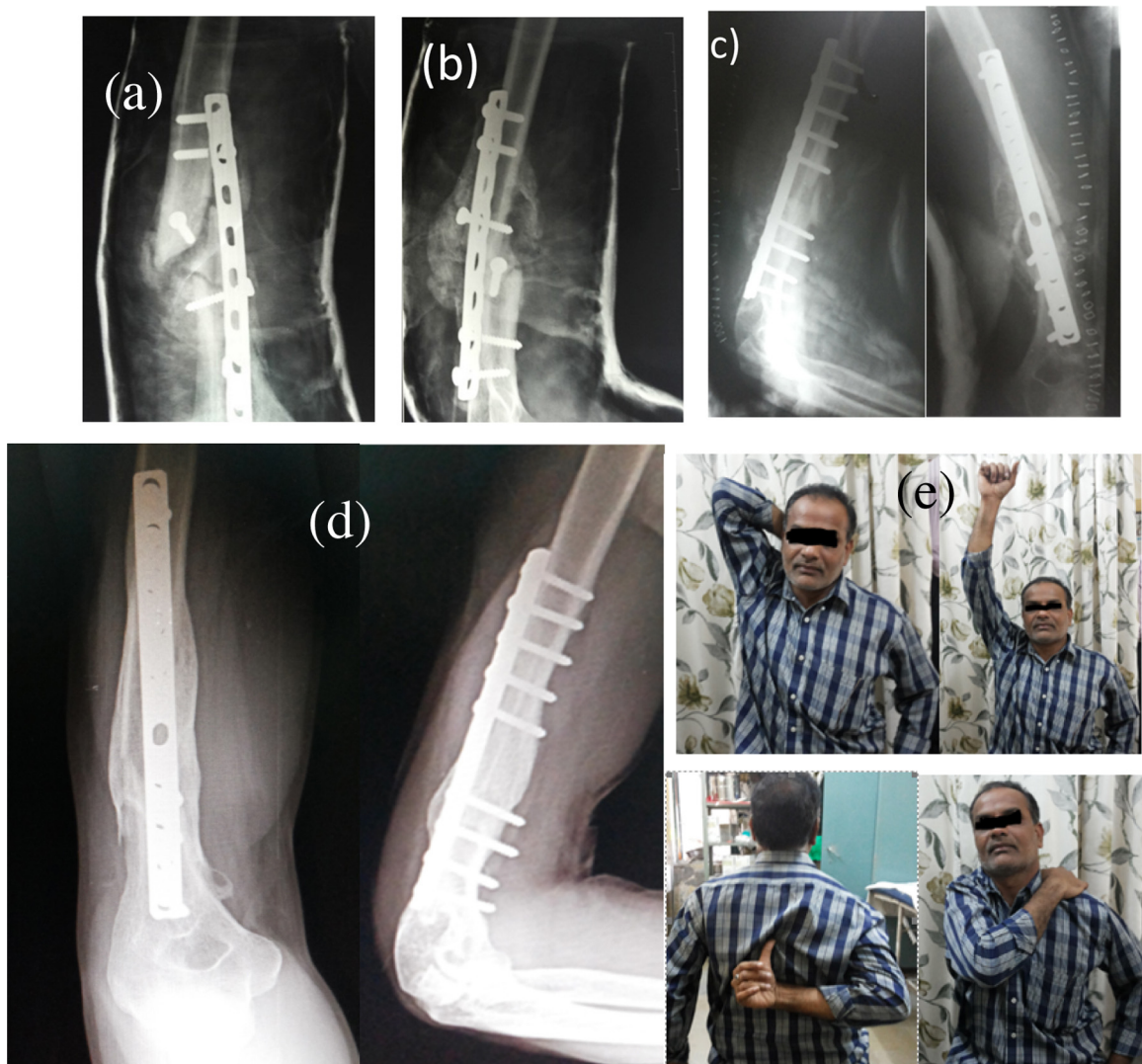
non-union at middle third junction, and 6 patients had non-union at middle third – distal third junction.

The mean duration of non-union was 4.43 yrs (range: 0.5–14 yrs). While the minimum duration of non-union was 6 months, only 5 cases had less than one year of duration of non-union, 9 cases had non-union in the range of 2–6 yrs and 3 cases had non-union as long as 10–14 yrs. Implant that has been used previously at the time of index procedure was DCP in 16 patients and LCP in one patient. Two patients underwent procedures twice with bone grafting in second procedure. Implant failure was observed in preoperative radiograph in 17 patients. Out of these, 8 patients had breakage of implant, 2 patients had broken screws alone and 11 patients had obvious radiological evidence of excessive bone loss, scalloping around screws, loosened implant with dislodged screws.

### 2.3. Surgical technique

All the patients underwent revision plate osteosynthesis of humerus along with intramedullary fibular strut graft. In the preoperative period, radiological assessment, complete blood

counts, erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) were done in all patients to rule out the possibility of latent infection. Posterior approach was used in 9 patients and anterolateral approach in 8 patients based upon previous approach and non-union site. The previous implant was removed and thorough debridement of non-union site was done, fibrous tissue excised, fracture ends freshened, and medullary canal recanalized on both sides with serial reaming with rigid K-nail reamers. An average length of 10.7 cm (range: 6–15 cm) fibular graft was harvested and kept as intramedullary strut. In one patient fibular graft was kept as onlay in distal fragment as there was extensive bone loss due to previous implant and the non-union site was at distal third shaft. In two patients, hemi-fibula was used as the medullary canal diameter was narrow. For osteosynthesis LCP was used in 4 patients and DCP in 14 patients. As far as possible in all cases at least 3 screws each were placed proximally and distally with quadricortical purchase. Additional iliac crest cortico-cancellous bone graft was used in 4 patients in whom there was extensive bone loss with scalloping due to previous implant.



**Fig. 1.** (a,b) A 48 yrs old male with 6 months duration of implant failure with non-union humerus distal third and AP, lateral radiograph suggestive of screw breakage implant loosening and comminuted type of non-union. (c) Treated with revision plating and ANVFG. (d) 94 months follow up suggestive of union. (e) With good functional outcome.

## 2.4. Follow-up and assessment

Postoperatively limb was immobilised in J-slab for 4 weeks. Active assisted shoulder and elbow exercises were started after 4 weeks. Patients were followed up at monthly interval till radiological union was seen and then at 6 months interval. The mean follow-up was 33.41 months (range: 12–94 months). Functional assessment was done by using DASH (Disabilities of the Arm, Shoulder and Hand) score both preoperatively and postoperatively at the time of final follow up.<sup>9</sup>

## 2.5. Statistical analysis

Statistical analysis was carried out by using the Graphpad Prism software. The nonparametric test, Wilcoxon signed-rank test was used to analyse the data.

## 3. Results

### 3.1. Radiological outcome

All fractures, except one, united following revision plating and intramedullary fibular strut graft procedure (Figs. 1–4). One patient had failure with implant bending but was clinically asymptomatic. The average time for union was 3.5 months (range: 3–5 months).

### 3.2. Complications

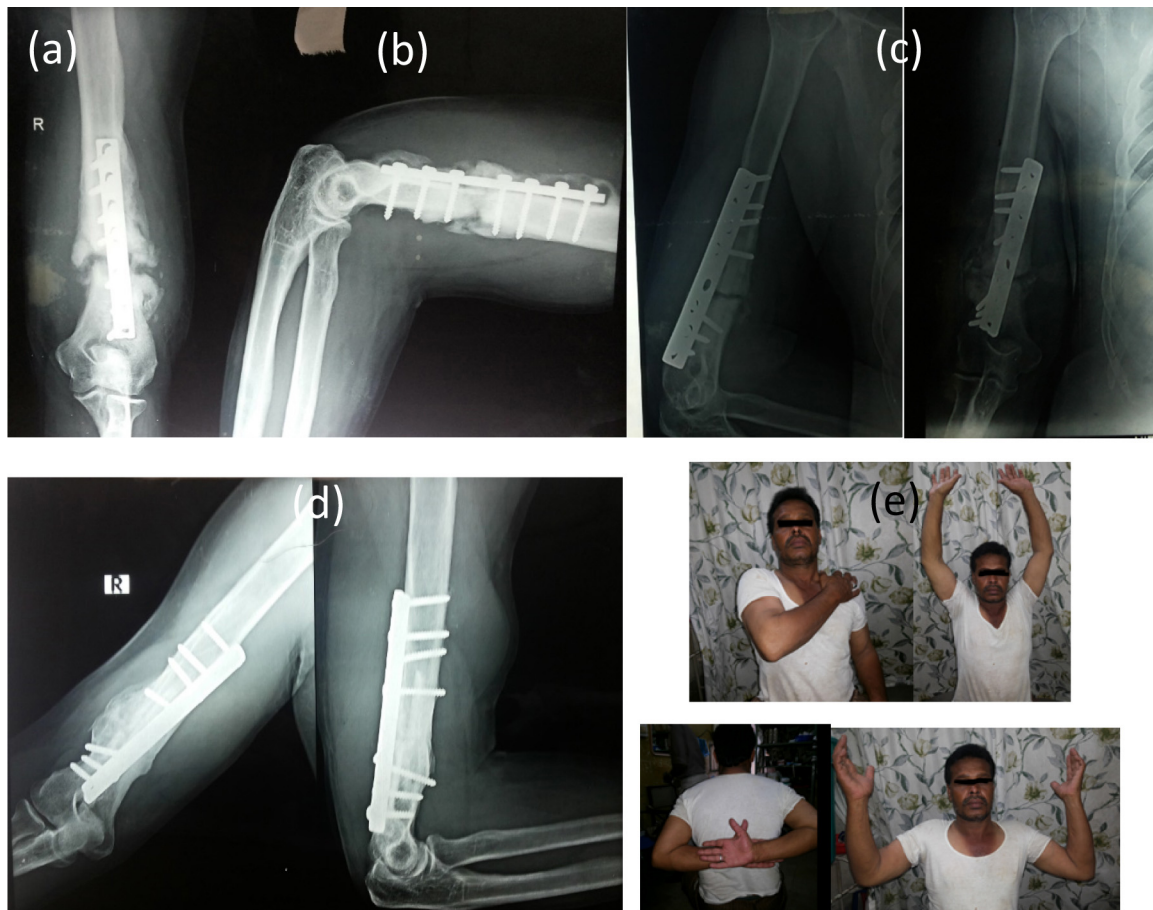
The complications included one patient with implant bending (Fig. 5). Possibility of failure in this patient is probably due to use of hemi-fibula which resulted in relatively less mechanical stability. In one patient iatrogenic fracture occurred during implant retrieval which eventually united (Fig. 6). One patient had transient radial nerve palsy postoperatively which recovered during follow up by 3 months. Another patient had transient ulnar nerve palsy which recovered in due course of time. There was no case of graft site morbidity, peroneal nerve palsy and infection – either at the fracture site or graft donor site.

### 3.3. Functional outcome

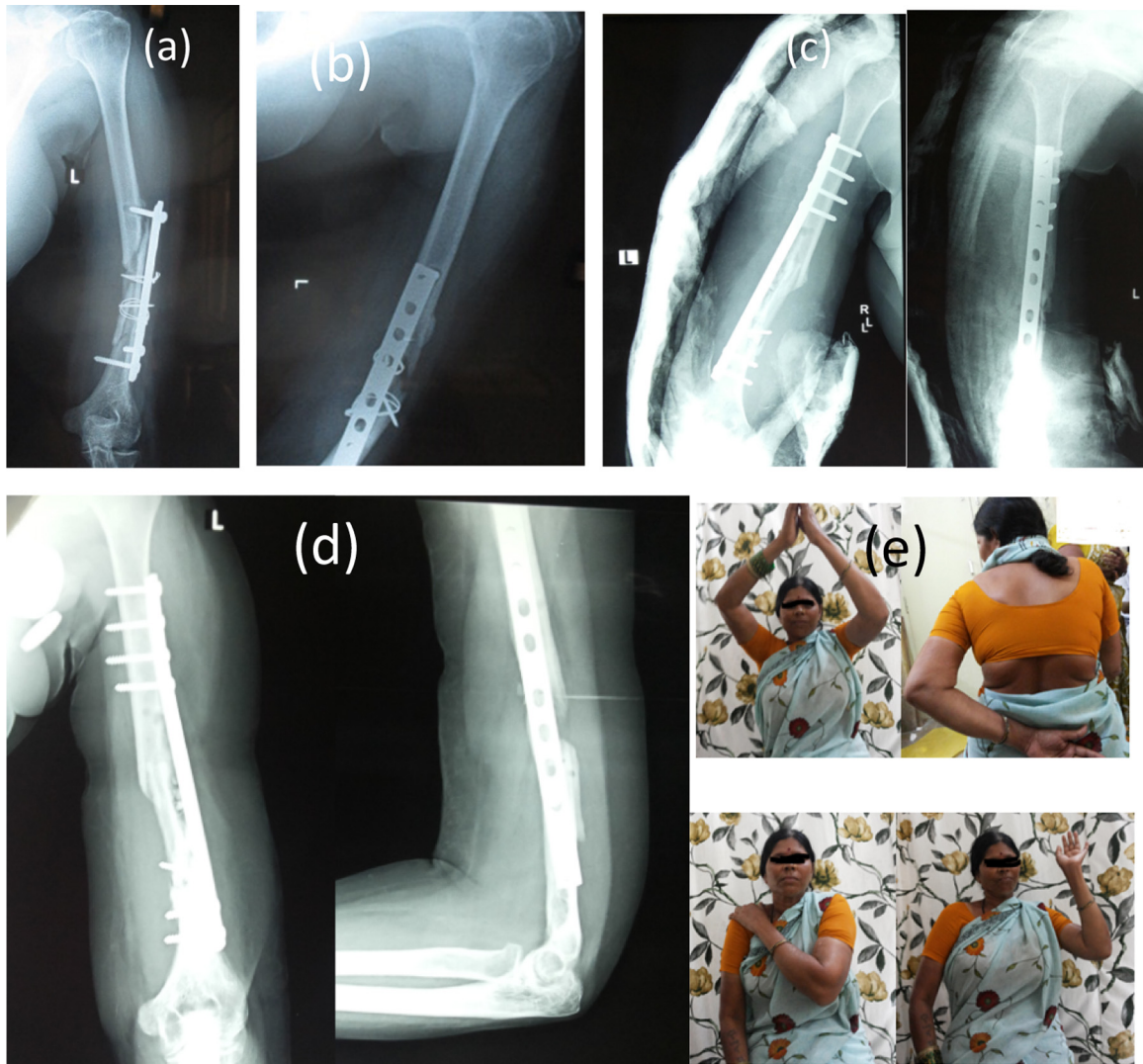
The functional outcome which was assessed by DASH score improved significantly from 59.14 (range: 43.6–73.21) preoperatively to 23.39 (range: 8.03–34.2) postoperatively at the final follow up ( $p=0.0003$ ) (Fig. 7).

## 4. Discussion

Patients with non-union with implant failure previously treated with internal fixation by plating, exhibit profound metal reaction leading to metallosis with implant breakage, metal debris, bony erosion with extensive bone loss, scalloping around screws and osteopenia. These cases are relatively uncommon, especially



**Fig. 2.** (a,b) A 42 yrs male with 7 months duration of implant failure non-union distal third humerus. (c) Treated with revision plating and ANVFG. (d) 36 months follow up suggestive of union at fracture site. (e) With good functional outcome.



**Fig. 3.** (a,b) A 45 yrs old female with 6 months duration of implant failure non-union, and AP, lateral radiograph suggestive of comminuted type of non-union. (c) Treated with revision plating and ANVFG. (d) 7 months follow up suggestive of union. (e) With good functional outcome.

difficult to manage with routine procedures and there is dearth of literature regarding management, which is a challenge for orthopaedic surgeons. While a number of methods of management of atrophic non-union have been described each has its own drawbacks.<sup>10</sup> Osteosynthesis with plating, intramedullary nailing, and Ilizarov technique have been described in various studies.<sup>10–19</sup> Bone grafting in the form of iliac crest bone graft, fibular strut graft either vascularised or nonvascularised, and autologous or allograft have been described in the management of non-union of humeral shaft fractures.

Dynamic compression plating has been utilized by several authors in the management of the non-union humeral fractures and high rates of union have been claimed.<sup>13,20–22</sup> It enables compression at fracture site, correction of axial malalignment, stimulation of osteogenesis (by shingling and bone grafting) in a single procedure. It can be applied with great success in non-union humeral fractures that have been managed conservatively with reasonable bone quality and without any implant in situ at the time of osteosynthesis. However, in cases of implant failure with poor bone quality and screw purchase, instead of DCP, LCP may be a reliable option.<sup>19,23</sup> But, as observed in the present study, in cases

with extensive bone destruction due to previous implant even LCP alone may not provide adequate stability and may not be a reliable option alone.

Osteopenia as a result of disuse, due to generalised metabolic cause, and previous implant stress shielding along with previous screw hole will interfere with the strength and purchase of the screws inserted subsequently during osteosynthesis.<sup>24,25</sup> Polymethylmethacrylate (PMMA) bone cement has been used to augment the purchase of the screws in osteoporosis, but it carries risks of foreign body reaction, infection, harmful effects on bone vascularity and on fracture healing, in case of inadvertent extrusion into the fracture site.<sup>26,27</sup> It may also cause death of the adjacent cells and inhibit biologic aspects of healing due to heat liberated during exothermic reaction. Many techniques have been suggested for improving the strength and purchase of screws like exchange of loose 4.5 mm cortical screws with 6.5 mm cancellous screws, onlay and inlay fibular strut graft and application of supplementary intramedullary plate to substitute for a deficient opposite cortex.<sup>14,8,29</sup> Double plating using two DCP at right angles to each other has also been described.<sup>6</sup> But onlay graft and double plating



**Fig. 4.** (a,b) A 35 yrs old male with 10 yrs duration of implant failure non-union, and AP, lateral radiograph suggestive of screw breakage, atrophic type of non-union with sclerosis of fracture ends. (c) Treated with revision plating and ANVFG. (d) 10 months follow up radiograph suggestive of union. (e) With fair functional outcome.

require extensive soft tissue stripping and devascularisation of humerus.

Screw purchase is directly related to the cortical thickness and bone mineralization.<sup>24,30</sup> The concept of quadricortical plating through intramedullary fibular strut graft was first described by Wright et al.<sup>7</sup> In his cadaveric study on biomechanical properties of strut graft, he demonstrated that the construct strength of

quadricortical fixation was similar to that of bicortical fixation augmented with bone cement and significantly stronger than bicortical fixation. This improved mechanical environment may reduce risk of fibrous non-union or failed fixation that can occur as a result of excessive motion and osteoporotic bone.

Locked intramedullary nailing has been used for primary osteosynthesis of humeral shaft fractures. However, exchange



**Fig. 5.** (a,b) A 27 yrs old with 8 months old implant failure non-union Lt humerus and AP, lateral radiograph suggestive of implant breakage. (c) Treated with revision plating and hemi-fibular graft. (d) 4 months follow up radiograph suggestive of implant failure with bending. (e) With fair functional outcome.

nailing or nailing in post implant failure cases is not successful in humeral non-union because of absence of cyclical loading due to weight bearing and higher amount of distractive and torsional loads on the humerus.<sup>17</sup> In addition, intramedullary nailing has been reported to carry higher complication rates including persistent shoulder pain, subacromial impingement, rotator cuff injury, iatrogenic fracture comminution or progression, and higher rates of delayed and non-union.<sup>31,32</sup> Unreliability of exchange nailing for management of non-union humeral fractures has further been documented by several authors.<sup>16,17</sup>

The Ilizarov external fixation has been used by several authors in the management of humeral non-union.<sup>10,11,15,18</sup> However, the disadvantages with this procedure include presence of bulky apparatus on the arm, pin tract infections, painful impingement of the frame on the trunk and risk of neurovascular injury associated with wire insertion. It has a distinct advantage in the management of infected non-union. Time commitment, complexity of procedures, and non-compliance of the patients make it an unreliable and rather unnecessarily complex option in non-infected non-union.

The role of vascularised fibular graft in humeral non-union with bone defect has been described by several authors with successful union rate.<sup>5,28,29,33</sup> But the technically demanding nature of the surgery, need for micro-vascular surgical procedure and increased cost of surgery make it an unreliable option in developing countries with less hospital infrastructure. Moreover it has been associated with risk of thrombosis of vascular pedicle. In elderly people with atherosclerotic disease vascularised fibular graft is contraindicated.

The nonvascularized fibular graft is easy to harvest with least possible tissue trauma and least graft site morbidity. The cortical bone gives immediate structural stability at fracture site. Intramedullary fibular strut act as an internal splint giving stability at fracture site and also increases screw purchase as described by Wright et al.<sup>7</sup> Several authors have shown successful results with the non-vascularized fibular graft (Table 2).<sup>7,15,34–39</sup> However, the grafts longer than 6cm have been shown to have decreased capacity for incorporation and healing. [28,40] The drawbacks to this technique are possibility of disruption of both endosteal and periosteal blood supply, iatrogenic fracture during insertion of graft and possible nerve palsy.



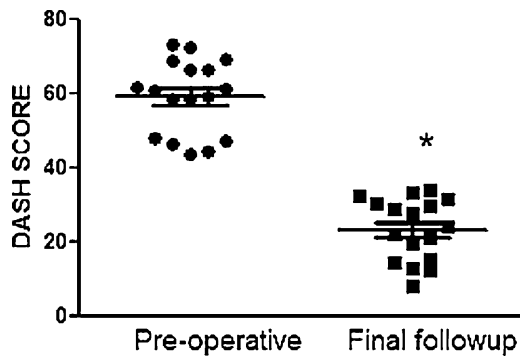
**Fig. 6.** (a,b) A 30 yrs old male patient with implant failure non-union Rt humerus and AP, lateral radiograph suggestive of implant breakage, sclerosis of fracture ends and atrophic type non-union. (c) Treated with revision plating and ANVFG. Arrow showing intraoperative iatrogenic distal third fracture during implant retrieval. (d) 12 months follow up radiograph suggestive of union at fracture site and iatrogenic fracture site. (e) With good functional outcome.

To the best of our knowledge, present study is the largest comprising 17 cases where autologous fibular graft was used in humeral shaft nonunions after failed plate fixation (Table 2). Wright et al.,<sup>7</sup> was first to describe the use of intramedullary fibular strut graft along with DCP in non-union humeral fractures. They used both autograft and allograft in 8 patients. Vidhyadhara et al.,<sup>39</sup> described the use of intramedullary fibular strut, as a novel adjunct to plating in atrophic non-union of humerus in 6 patients. Kumar et al.<sup>23</sup> studied 24 cases of humeral shaft nonunions following failed internal fixation treated with LCP and autologous bone graft. Only three cases were treated with fibular graft. In our study we

have used DCP in all cases except three where we have used LCP and we are of the opinion that LCP is not mandatory in treating these type of cases so long as fibular graft is used as an adjunct. The drawback of present study was that it is not a comparative study and cannot differentiate between the use of LCP and DCP in implant failure non-union humerus with significant cortical defect; we also did not have a matched control group treated without use of fibular graft.

We have observed that patients with non-union humerus previously treated with plate fixation present late despite non-union, which is the reason for metallosis, bone loss around screws





**Fig. 7.** The functional assessment by DASH score in pre-operative and at final follow up. (\* P=0.0003)

necessitating the use of fibular graft. We had patients who presented as late as 10–14 yrs (*vide* Section 2.2 and Table 1). In our study, the average length of fibular graft used was 10.88 cm (range: 6–15 cm). According to current literature, a nonvascularized fibular graft >6 cm has relatively decreased capacity for incorporation and healing.<sup>5,28,40</sup> Augmentation with iliac crest graft, as we have done in 4 cases, in the presence of large cortical defect created by previous implant will increase the incorporation and healing; and probably combination of longer fibular graft and iliac crest graft

may form an alternative to complicated vascularised fibular graft procedures in developing countries. But to confirm, we need to do similar study in larger population group along with a control group.

## 5. Conclusion

The findings from our study show that revision plating along with autologous nonvascularized fibular graft is a reliable option in humeral diaphyseal non-unions with failed plate-screw osteosynthesis with significant cortical defect to achieve adequate screw purchase, stability at fracture site and high chance of union with good functional outcome.

## Conflict of interest

The authors have none to declare.

## Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Acknowledgement

The authors would like to thank Dr. Vijay Kumar Kutala for his valuable help in statistical analysis and proof reading of the article.

**Table 2**  
Comparison with other studies in the literature where fibular graft was used in treating humeral non-unions.

Study	No of Subjects (FG Used)	Properties of Study; Procedure Done	Average Age (yrs)	Mean Interval of Nonunion	Mean Follow Up (months)	Duration of Union (months)	Results	Complications
Wright et al. <sup>7</sup>	9 (9)	8 cases of failed fixation; DCP+Allograft in 4 pts & Autograft in 5 pts, also biomechanical analysis of fibular graft assessed	49.8 (28–67)	16.25 (3.5–72) months	38.6 (12–74)	3.37 (3–4)	8 achieved union	1-nonunion, 1- radial nerve palsy, 1-supracondylar fracture, 1-peroneal nerve palsy
Farouk O et al. <sup>38</sup>	10 (10)	3 cases of failed plating; DCP+FG	–	16 (6–36) months	10 (8–16)	4 (3–6)	10 achieved union	stress supracondylar fracture
Vidhyadara S et al. <sup>39</sup>	6 (6)	in osteoporotic humerus, 1 case of failed fixation; DCP+FG	65.33 (54–84)	13.33 (7–26) months	15.83 (11–24)	3	all achieved union DASH score 84 ± 5 to 28 ± 13	1- transient peroneal nerve palsy, 1-iatrogenic splinter, 2-superficial infection
Kilic A et al. <sup>34</sup>	4 (4)	3 cases of failed fixation; DCP+FG	67 (65–69)	–	48 (36–72)	3.2 (3–4)	union in all DASH score ≥58–17	nil
Erder ER et al. <sup>35</sup>	5 (5)	2 cases of failed plating; LCP+FG	49.2	70 (24–128) months	22.8 (12–36)	5 (4–5.5)	union in all with Constant Murley score of 88	nil
Gopisankar et al. <sup>36</sup>	7 (7)	infected nonunions with mean previous surgery of 2.7; DCP+FG	40 (29–59)	–	15 (13–24)	5.4 (4–8)	6 achieved normal function, 1 has brachial plexus injury with poor outcome	2 case of wound infection
Padhye KP et al. <sup>15</sup>	35 (4)	infected, noninfected, osteoporotic nonunion included. Ilizarov, plating ± BG	42 (24–71)	–	16 (6–60)	infected-6.5, noninfected – 5, osteoporotic-10	union achieved in all	pin site complications in Ilizarov cases
Willis MP et al. <sup>37</sup>	20 (20)	10 cases of failed fixation, LCP+ fibular allograft	61 (44–81)	–	36 (12–94)	4	19 achieved union with normal daily activities	1- nonunion, 3-adhesive capsulitis of shoulder
Kumar MN et al. <sup>23</sup>	24 (3)	all cases of failed fixation, LCP ± BG	41.04 (24–57)	26.3 (7–276) months	39 (27–65)	–	23 attained union,	2- delayed union, 1- persistent nonunion, 2- transient radial nerve palsies
Our Study (2015)	17 (17)	17 cases are previously operated, 2 cases operated twice	40.11 (26–57)	53.17 (6–168) months	33.41 (12–94)	3.5 (3–5)	16 attained union with DASH score ≥59.14–23.39	1- implant bending, 1- transient radial nerve palsy, 1- transient ulnar nerve palsy, 1-iatrogenic splinter during implant removal.

(FG – Fibular Graft, BG – Bone Graft, DCP – Dynamic Compression Plate, LCP – Locking Compression Plate.

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