Acute Strut Fibular Autograft Augmenting Osteosynthesis for High Energy Humeral Fractures

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The Egyptian Orthopedic Journal; 2021 supplement (1), June, 56: 46-53

Abstract:

Background:
Surgical management of humeral fractures is indicated when the fracture is unstable, irreducible, open, pathological, associated with vascular or nerve injuries or part of floating elbow configurations. When these fractures are of high energy pattern, surgical management becomes more challenging.

Objective:
To assess the efficacy and reproducibility of non-vascularized strut fibular autograft application in the acute setting of high energy humeral fractures regarding stability of fixation, adequacy of reduction and union.

Patients and Methods:
Sixteen patients were recruited from October 2009 to January 2016 in a prospective cohort entailing application of acute non-vascularized strut fibular autograft augmenting osteosynthesis for management of high energy humeral diaphyseal or meta-diaphyseal fractures. Bony union, the disability of arm, shoulder and hand (DASH) score, active range of motion of the elbow and shoulder in addition to complications were recorded and evaluated.

Results:
The mean follow up period was 28.9 ± 5 months. The mean time to good bony union was 23.9 ± 4.5 weeks [range: 16-32]. The mean active elbow flexion was 122.8° ± 9.3 [range: 100-130] while the mean elbow lag of extension was 6.3° ±7 [range: 0-20]. The mean active abduction/adduction range of motion of the shoulder was 154.4° ± 9.6/73.1°± 7 [range: 130-160 / 60-90]. The mean postoperative DASH score was 10.3 ± 6.3 [range: 4.7-22].

Conclusions:
Acute application of strut fibular autograft augmenting osteosynthesis in cases of complex high energy humeral fractures both in the open or closed settings provides an efficient tool to improve fracture reduction, stability of fixation and consequently promote union.

Keywords:
Complex high energy humeral fractures, acute strut fibular autograft, osteosynthesis.

Introduction:

Complex high energy humeral fractures, whether being of metaphyseal, diaphyseal or combined metaphyseal-diaphyseal nature, represent a major dilemma to the orthopaedic upper limb surgeons. This could be owed to both biomechanical and biological peculiarities of these fractures. Biomechanically, the humeral diaphysis is subjected to multiple deforming forces including muscle groups acting on both shoulder and elbow. Biologically, the nutrient foramen enters the humeral medulla at its medial proximal third as a branch from the brachial artery. Subsequently, if this artery is damaged either traumatically or iatrogenically, the endosteal blood supply gets disrupted leaving the bone depending solely on the intricate periosteal blood supply with increased incidence of nonunion [1]. Eventually, when these fractures are open or associated with severe comminution, segmental bone loss or soft tissue damage, the challenge becomes magnified [2].

Humeral diaphyseal fractures account for 1-3 % of all adult fractures [3]. In any case of fracture, the decision making takes into consideration: (1) fracture personality entailing fracture pattern, degree of comminution, bone quality, soft tissue envelop status and local vascularity, and (2) patient related factors such as age, dominance and level of activity.

When dealing with humeral fractures, surgical management is indicated when such fractures are irreducible, open, pathologic, associated with vascular or nerve injuries, associated with ipsilateral forearm fractures [floating elbow], or when the fracture pattern is unstable [short oblique or transverse] in active adult patients [4].

When confronted with high energy open humeral fracture, the orthopaedic surgeon may adopt either primary or secondary reconstruction. In the setting of primary reconstruction, open or closed reduction with internal or external fixation methods could be used. The addition of bone grafts whether autografts [nonvascularized or vascularized], allografts, xenografts or synthetic bone grafts could be used.

The implication of secondary reconstruction after initial debridement is preferred in cases with delayed presentation, potential infection or initial high energy trauma with poor soft tissue condition.

However, the use of nonvascularized fibular autograft for such conditions in the acute settings has rarely been discussed in the literature [5].
In cases of high energy humeral fractures, whether closed or open, implying high degree of osseous comminution with favourable soft tissue envelop, an extremely difficult situation is created to reconstitute the initial bone geometry.
In such situation, it seems rational to make use of non-vascularized strut fibular autograft [SFG] as a template over which the comminuted bone fragments are aligned. The authors of this study postulate that using [SFG] in the acute setting of high energy humeral fractures will yield more reproducible results regarding stability of fixation, better reduction and union.
This study was approved by our center human ethical committee on July 2009. The study was conducted in accordance to the Declaration of Helsinki and Good Clinical Practice (GCP) guidelines, and all care was taken to maintain patient safety and confidentiality.

Patients and methods:

Sixteen patients were recruited from October 2009 to January 2016 in a prospective study comprising the application of acute non-vascularized [SFG] augmenting osteosynthesis for management of high energy humeral diaphyseal or meta-diaphyseal fractures. A full informed consent was obtained from each individual patient included in this study declaring the nature of the procedure and the possible complications that could be encountered.
This study included 12 male and four female patients with a mean age of 37.6 ± 12.4 years [range; 18-58]. Eleven left and five right humeri were affected in fourteen right and two left sided dominant patients. The mechanism of injury varied from motor vehicle accident [MVA] in seven patients, firearm injury [FAI] in six patients, falling from height [FFH] in two patients and only one patient sustained a motorcycle accident [MCA]. Ten open fractures were included ranging from grade I to grade IIIA according to Gustilo and Anderson grading system [6]. The remaining six cases were closed fractures. Ten cases had middle third humeral fractures; four cases had fractures at the proximal meta-diaphysis; while the remaining two cases had fractures at the distal meta-diaphysis. Index surgery took place at a mean time of 24.4 ± 25.7 hours [range; 8-96 hours] from the onset of injury while open fracture cases had their surgeries performed at an average time of 11.4 hours [range; 8-18 hours]. Eight cases had associated other visceral, bony or peripheral nerve injuries while the remaining eight cases had isolated humeral fractures **(Table 1).**

Table 1: Patients' demographic data.

Patient number	Age	Sex	Side	Occupation	MOT	Fracture pattern	Time to interference [hours]	Dominance	Associated injuries
1	48	M	Lt.	Farmer	FAI	**Open** Comminuted proximal 2/3 of the humerus	8	Rt.	
2	56	F	Rt	housewife	FAI	**Open** Comminuted distal 1/3 of the humerus	12	Rt.	Intestinal injury [colectomy]
3	38	M	Lt	Driver	MCA	Closed Comminuted middle 1/3 of the humerus	12	Rt.	Fracture femur and both bones forearm
4	32	F	Rt	University staff member	FAI	**Open** Comminuted proximal 1/3 of the humerus	8	Rt.	Median nerve injury
5	40	M	Lt.	Worker	MCA	Closed Comminuted distal 1/3 of the humerus	48	Rt.	Left tibial fracture
6	24	M	Rt.	Worker	MCA	**Open** Comminuted middle 1/3 of the humerus	12	Rt.	Right femur fracture
7	42	M	Lt.	Worker	FAI	**Open** Comminuted proximal 2/3 of the humerus	8	Rt.	
8	28	M	Lt.	Worker	FAI	**Open** Comminuted middle 1/3 of the humerus	12	Rt.	
9	30	M	Lt.	Farmer	MCA	closed Comminuted middle 1/3 of the humerus	72	Rt.	
10	18	M	Rt.	College student	MCA	Closed Comminuted middle 1/3 of the humerus	96	Rt.	Ipsilateral fracture clavicle
11	18	F	Lt.	College student	MCA	Closed Comminuted middle 1/3 of the humerus	24	Rt.	
12	38	M	Lt	Worker	FFH	Closed Comminuted proximal 2/3 of the humerus	24	Rt.	
13	46	M	Rt.	Farmer	FAI	**Open** Comminuted middle 1/3 of the humerus	12	Lt.	Radial nerve injury
14	52	F	Lt.	Housewife	FFH	**Open** Comminuted middle 1/3 of the humerus	16	Rt.	
15	58	M	Lt.	Medical service employer	MVA	**Open** Comminuted middle 1/3 of the humerus	18	Lt.	Radial nerve injury
16	34	M	Lt.	Manual worker	MCA	**Open** Comminuted middle 1/3 of the humerus	8	Rt.	
Mean ±SD	37.6± 12.4						24.4 ± 25.7		

MOT: mechanism of trauma; **FAI:** firearm injury; **MVA:** motor vehicle accident; **MCA:** motor cycle accident; **FFH:** falling from height; **SD:** standard deviation.

Inclusion criteria:

(1) age ≥ 18 years, (2) high energy multifragmentary fractures which are inamenable for anatomical reduction or interfragmentary compression **(Figure 1A)**, (3) closed or open fractures Gustilo-Anderson grades I-IIIA, (4) extra-articular fractures extending at the diaphysis or meta-diaphysis of the humerus up to 3 cm from the proximal or distal bony ends, and (5) minimum follow up of 2 years.

Exclusion criteria:

(1) patients before skeletal maturity to prevent bias in the results, (2) pathological fractures, (3) immunocompromised patients, and (4) patients having previous history of elbow or shoulder trauma that could make the final results unreliable.

Preoperative radiological workup:

Standard radiographs in two perpendicular views [anteroposterior and lateral] in addition to traction views were routinely performed on the involved humeri to have a good and thorough preoperative assessment of the fracture pattern and magnitude of bone defect.

Surgical technique:

Under general anaesthesia, the patient was positioned supine with the affected upper limb on a side table. Two-team approach was adopted where one team harvests the fibula from the contralateral lower limb through a standard lateral or posterolateral approach in a subperiosteal fashion. The length of the harvested fibula was routinely 2-4 cm longer than the length of bony defect or the extent of the comminution encountered in humeral fracture.

Simultaneously, the second team approaches the initial fracture through the standard deltopectoral approach or its extension through the distal arm where the following steps were performed: in case of open fractures, initial aggressive and thorough debridement was performed including excision of any devitalized soft tissues or loose bone fragments making sure to preserve all viable bony fragments even if so small. In cases of fractures involving the proximal two thirds or the middle third of the humeral diaphysis, the medullary canal was prepared both at the most proximal and distal extensions of the comminution by reaming till the diameter was suitable to receive the fibular graft. The harvested fibula was then indwelled into the medullary canal of the humeral diaphysis **(Figure 1B).** Alternatively, one or both sides of the fibular autograft were osteotomized in a step cut fashion in cases of narrow medulla or fractures of the distal meta-diaphysis. This was followed by osteotomizing both ends of the humerus in a step cut fashion to coapt with the prepared ends of the harvested fibula.

The [SFG] is now in place where it was encased by the viable comminuted bony fragments. Finally, the fracture was stabilized using narrow DCP, broad DCP or anatomical proximal humeral locking plates 4.5 mm. In case the fibula was stable in situ, no screws were used to stabilize it but in case it was unstable one or two screws were used to fix it to the overlying plate. Finally, a redivac was inserted and the wound was closed in layers.

Postoperative care:

The operated arm was routinely protected in a removable arm orthosis. The redivac was removed after 48 hours. The stitches were removed at the 14th postoperative day.

All patients were instructed to undergo passive range of motion [ROM] exercises of the shoulder and elbow from day one postoperatively till the end of the second week under supervision of an upper limb professional physiotherapist. This was followed by protected active [ROM] from the start of third week till the end of sixth week. Gradual unprotected active [ROM] was first allowed according to the progress of bony union **(Figure 1C-E)**.

Follow up:

All patients were followed up in a standard manner. Radiologically, standard radiographs of the involved humeri in both anteroposterior and lateral projections were obtained immediate postoperatively, then after six weeks, 12 weeks, six months, 12 months and then yearly. Bony union was evaluated by the grading proposed by Hariri et al where union was classified into good [union of both ends of fracture without the need for more procedures], intermediary [to achieve union the treating surgeon needed one or more further surgeries], poor [nonunion] [7]. Clinically, the disability of arm, shoulder and hand (DASH) score [8], the active [ROM] of the elbow and shoulder and complications were recorded and evaluated.

Figure (1): showing: (A): Comminuted fracture of the proximal 1/3rd of the humerus as a result of firearm injury with the bullet retained in the humeral head; (B): Open reduction and internal fixation using anatomical locked proximal humeral plate with acute application of autogenous strut fibular graft with preservation of the comminution surrounding the fibula; (C): good union at the end of third postoperative month. ; (D): good union at the end of sixth postoperative month. ; (E): complete solid union at the end of first postoperative year with incorporation of the comminuted fragments.

Statistical analysis:

All data were collected, filed and tabulated in the SPSS [statistical package for social sciences]; version 13 for windows. Quantitative data were expressed as range / mean ± SD. Independent samples T test was used for parametric quantitative data between two groups while the Mann Whitney test was used for non-parametric quantitative data between two groups. Fisher exact test was used for qualitative data between the two groups. The level of significance was determined at (*p*) value < 0.05.

Results:

All patients included in this study were followed up for a minimum period of 24 months; [mean= 28.9 ± 5; range: 24-40] **(Table 2)**. The mean extent of comminution was 6.6 ± 1.6 cm [range: 5-10].

The mean length of the harvested fibula was 9.5 ± 1.7 cm [range: 8-12] while the mean length of the grafted fibula was 9 ± 1.9 cm [range: 7-12].

The mean time to good bony union according to the criteria used by Hariri et al [7] was 23.9 ± 4.5 weeks [range: 16-32].

Table 2: Results of the study.

Patient	Extension of comminution [cm]	Length of harvested fibula [cm]	Length of grafted fibula [cm]	Time to union [weeks]	Follow up [months]	Method of fixation	Complications	DASH score
1	10	12	12	24	36	APHLP	None	5.1
2	6	8	8	16	24	Narrow DCP	None	4.7
3	8	12	12	24	24	Narrow LC-DCP	Infection	19
4	6	10	8	32	40	APHLP	None	22
5	5	8	7	18	30	Narrow DCP	None	5
6	7	10	10	20	30	Narrow DCP	None	5.2
7	6	8	8	20	28	Broad DCP	Postoperative myocardial infarction	10.8
8	5	8	8	24	30	Narrow DCP	None	7.5
9	6	10	8	30	24	Narrow DCP	None	5.8
10	5	8	8	22	28	Narrow DCP	None	11
11	6	10	8	20	30	Narrow DCP	None	5
12	8	12	12	26	36	Broad DCP	None	5.2
13	10	12	12	30	30	Broad DCP	None	21
14	6	8	8	26	24	Broad DCP	Infection	9
15	5	8	7	24	24	Broad DCP		19
16	6	8	8	26	24	Broad DCP		8.7
Mean ±SD	6.6±1.6	9.5±1.7	9 ± 1.9	23.9±4.5	28.9±5			10.3±6.3

APHLP: anatomical proximal humeral locked plate; **DASH:** disability of arm, shoulder and hand score; **DCP:** dynamic compression plate; **SD:** standard deviation.

The elbow and shoulder postoperative active [ROM] were analyzed **(Table 3)**; the mean active elbow flexion was 122.8° ± 9.3 [range: 100-130] while the mean elbow lag of extension was 6.3° ±7 [range: 0-20].

Regarding shoulder; the mean active shoulder flexion was 153.1° ± 10.8 [range: 130-160] while the mean active shoulder extension was 86.3°± 8.1 [range: 70-90]. The mean active abduction/adduction [ROM] was 154.4° ± 9.6/73.1°± 7 [range: 130-160 / 60-90]. The mean active external rotation was 82.2° ± 9.8 [range: 60-90] while the mean active internal rotation was 75.9° ± 8.4 [range: 50-80]. Regarding the mean postoperative DASH score, it was 10.3 ± 6.3 [range: 4.7-22].

Table 3: Postoperative active range of motion [ROM] results.

Patient	Elbow flexion [°]	Elbow lag of extension [°]	Shoulder ROM [°] Flexion	Extension	Adduction	Abduction	External rotation	Internal rotation
1	130	0	160	90	70	160	90	80
2	120	10	160	90	70	150	80	80
3	100	20	160	90	70	140	70	70
4	130	0	160	90	70	160	90	80
5	125	15	160	90	70	160	90	80
6	130	0	150	90	60	160	80	80
7	130	0	160	90	70	160	90	80
8	130	0	160	90	70	160	90	80
9	120	10	150	90	80	160	80	80
10	110	15	130	70	80	150	60	50
11	130	0	160	90	70	160	90	80
12	110	10	130	70	80	130	65	65
13	130	0	160	90	70	160	90	80
14	120	10	140	70	90	140	80	70
15	120	10	150	90	80	160	80	80
16	130	0	160	90	70	160	90	80
Mean ±SD	122.8 ±9.3	6.3±7	153.1 ± 10.8	86.3± 8.1	73.1± 7	154.4 ± 9.6	82.2±9.8	75.9±8.4

SD: standard deviation.

Patients who sustained open fractures have been compared to those having closed fractures **(Table 4)**. The mean time lag to the index surgery was significantly lower in the open fracture group in comparison to the closed fracture group being 11.4 ± 3.5 hours [range: 8-18] versus 46 ± 32.6 hours [range: 12-96] respectively *(p=0.048)*. Regarding the time to good union, there was no statistically significant difference between both groups (p= 0.721). Regarding the postoperative DASH score it was better in the closed fracture group than in the open fracture group but in a nonsignificant way [8.5 ± 5.6 versus 11.3 ± 6.8 respectively; p=0.384]. Interestingly, the mean active elbow flexion was significantly better in the open fracture group [127° ± 4.8 versus 115.8° ± 11.1; *p= 0.004*] and the lag of elbow extension was significantly lower in the open fracture group [3 ± 4.8 versus 11.7 ± 6.8; *p=0.016*]. The authors attribute this to the faster surgical interference and more closely observed rehabilitation program.

Table 4: Comparison between the results of open fracture and closed fracture patients.

	Fracture Open (n=10)	Closed (n=6)	P value
Time to interference [hours]	(8-18) / 11.4±3.5	(12-96) / 46±32.6	0.048*
Extension of comminution [cm]	(5-10) / 6.7±1.8	(5-8) / 6.3±1.4	0.679
Length of harvested fibula [cm]	(8-12) 9.2±1.7	(8-12) 10±1.8	0.384
Length of grafted fibula [cm]	(7-12) 8.9±1.8	(7-12) 9.2±2.2	0.796
Time to union [weeks]	(16-32) 24.2±4.8	(18-30) 23.3±4.3	0.721
Follow up [months]	(24-40) 29±5.5	(24-36) 28.7±4.5	0.903
Site			
Distal	1(10%)	1(16.7%)	1
Middle	6(60%)	4(66.7%)	
Proximal	3(30%)	1(16.7%)	
Associated injuries			
No	5(50%)	3(50%)	
Intestinal	1(10%)	0(0%)	0.262
Fractures	1(10%)	3(50%)	
Nerve injuries	3(30%)	0(0%)	
Associated injuries			
No	5(50%)	3(50%)	1
Yes	5(50%)	3(50%)	
Complications			
No	8(80%)	5(83.3%)	1
Yes	2(20%)	1(16.7%)	
DASH score	(4.7-22) / 11.3±6.8	(5-19) / 8.5±5.6	0.384
Elbow flexion	(120-130) / 127±4.8	(100-130) / 115.8±11.1	0.004*
Elbow extension	(0-10) / 3±4.8	(0-20) / 11.7±6.8	0.016*
	Shoulder ROM		
Flexion	(140-160) / 156±7	(130-160) / 148.3±14.7	0.274
Extension	(70-90) / 88±6.3	(70-90) / 83.3±10.3	0.349
Adduction	(60-90) / 72±7.9	(70-80) / 75±5.5	0.428
Abduction	(140-160) / 157±6.7	(130-160) / 150±12.6	0.167
External rotation	(80-90) / 86±5.2	(60-90) / 75.8±12.8	0.113
Internal rotation	(70-80) / 79±3.2	(50-80) / 70.8±12	0.159

*****: p value < 0.05 which means the results are statistically significant. **DASH:** disability of arm, shoulder and hand score; **ROM:** range of motion.

A comparison was held according to the level of the fracture **(Table 5)** which yielded the following results; the mean time to union in the distally located fractures was significantly lower than those located in the midshaft *(p=0.03)* and lower than those located proximally but with no significance [17 ±

1.4, 24.6 ± 3.5, and 25.5 ± 5 weeks respectively]. Similarly, patients with distally located fractures have shown better postoperative DASH score than those with mid-diaphyseal fractures *(p=0.04)* or proximally located fractures [4.9 ± 0.2, 11.1 ± 6.2, and 10.8 ± 7.9 respectively]. When comparing the postoperative DASH score in cases associated with other injuries, the score was significantly better in cases of associated nerve injuries than those associated with fractures [8.5 ± 5.6 versus 11.3 ± 6.8 respectively, *p=0.049*]

Three patients have shown postoperative complications. Regarding recipient site complications; two cases have exhibited infection one of them had been managed successfully by single time debridement and administration of the proper antibiotic according to the culture and sensitivity testing and the other case had 3 sequential debridements but with persistent infection which necessitated the removal of the implant. Additionally, one case suffered from immediate postoperative myocardial infarction that was managed successfully by cardiology consultants of our center. Regarding the donor site morbidity, no single complication has been encountered including infection, temporary or permanent foot paraesthesia, valgus ankle deformity or even intolerable pain at the surgical site.

Table 5: Comparison according to the level of the fracture.

	Fracture			P value		
	Distal N=2	**Middle N=10**	**Proximal N=4**	**Distal vs Middle**	**Distal vs Proximal**	**Middle vs Proximal**
Time to union (range) (M±SD)	(16-18) 17±1.4	(20-30) 24.6±3.5	(20-32) 25.5±5	0.030*	0.064	0.718
Follow up(range) (M±SD)	(24-30) 27±4.2	(24-30) 26.8±3	(28-40) 35±5	0.905	0.159	0.023*
Associated inj.						
No	0(0%)	5(50%)	3(75%)			
Intestinal	1(50%)	0(0%)	0(0%)	0.106	0.200	0.748
Fractures	1(50%)	3(30%)	0(0%)			
Nerve injuries	0(0%)	2(20%)	1(25%)			
Associated inj.						
No	0(0%)	5(50%)	3(75%)	0.470	0.400	0.580
Yes	2(100%)	5(50%)	1(25%)			
Complications						
No	2(100%)	8(80%)	3(75%)	1	1	1
Yes	0(0%)	2(20%)	1(25%)			
DASH score	(4.7-5) 4.9±0.2	(5-21) 11.1±6.2	(5.1-22) 10.8±7.9	0.041*	0.064	0.832
Elbow flexion	(120-125) 122.5±3.5	(100-130) 122±10.3	(110-130) 125±10	0.733	0.325	0.528
Elbow extension	(10-15) 12.5±3.5	(0-20) 6.5±7.5	(0-10) 2.5±5	0.255	0.080	0.341
Flexion	(160-160) 160±0	(130-160) 152±10.3	(130-160) 152.5±15	0.227	0.480	0.636
Shoulder ROM						
Extension	(90-90) 90±0	(70-90) 86±8.4	(70-90) 85±10	0.507	0.480	0.843
Adduction	(70-70) 70±0	(60-90) 74±8.4	(70-80) 72.5±5	0.468	0.480	0.751
Abduction	(150-160) 155±7.1	(140-160) 155±8.5	(130-160) 152.5±15	0.797	0.784	0.929
External rotation	(80-90) 85±7.1	(60-90) 81±9.9	(65-90) 83.8±12.5	0.643	0.784	0.444
Internal rotation	(80-80) 80±0	(50-80) 75±9.7	(65-80) 76.3±7.5	0.396	0.480	0.929

*****: p value < 0.05 which means the results are statistically significant; **M:** mean; **SD:** standard deviation; **DASH:** disability of arm, shoulder and hand score; **ROM:** range of motion.

Discussion:

The main goal of the orthopaedic surgeon when dealing with humeral fractures is restoring painless normal preinjury activity with preservation of functional shoulder and elbow ROM. This could be fulfilled through maintaining humeral integrity both anatomically and biomechanically. This becomes extremely challenging when dealing with complex high energy fractures which pose extreme difficulty for reduction and fixation. In such cases, the use of intramedullary nailing, bridge plating, external fixators whether tubular or ring frames could be used. However, fracture healing could not be promoted in addition to the need for certain expertise for their application. The use of plate and screws osteosynthesis in cases of complex comminuted high energy humeral fractures may be difficult to achieve considering the long comminution distance, magnified stresses applied to the construct and the smaller intact fragments available for fixation. In such cases, it seems rational to augment the fixation construct with strut fibular autograft. This type of graft provides the surgeon with the following advantages: immediate stability of the fracture being an adjunct to the osteosynthesis, stronger purchase of the screws through quadricortical fixation, and easier templating for fracture reduction, providing a scaffold for the viable bony fragments within the fracture thus promoting the process of creeping substitution in addition to secondary fracture healing. This will eventually allow earlier rehabilitation thus precluding elbow or shoulder stiffness. This technique surpasses the technique of radical debridement of the comminuted fragments and achieving acute humeral shortening as the safe limits of shortening is 2 cm beyond which muscle weakness is observed [9].

Despite the fact that free vascularized fibula graft [FVFG] is favoured to [SFG] in reconstruction of major bony defects exceeding 6 cm for its well established advantages in the form of bypassing the process of creeping substitution to mimicking bifocal fracture, rapid fusion, hypertrophy and incorporation in non-vascular beds [7], [10] , [SFG] still has its evident role in reconstruction [5].

For a non-vascularized bone graft to achieve successful creeping substitution the underlying soft tissue bed must be healthy, vascular and infection free. Our concept is to make use of non-vascularized [SFG] in the acute setting of high energy trauma to make use of the healthy, vascular and infection free bed. Different studies have emphasized the potential continuing role of [SFG] in reconstruction of major long bone defects which may be secondary to trauma, infection, nonunion, pseudoarthrosis or post-tumour resection [11-13]. Interestingly, this technique has proved high efficiency in management of post-sequestrectomy bone defects in pediatrics [14]. El sayed et al [5] have used [SFG] for reconstruction of posttraumatic bone defects averaging 7 cm [range 6-10 cm] in 12 cases of tibial, humeral and ulnar fractures. Eleven cases achieved bony union in an average period of time of 4.5 months with ten excellent, one good and one poor functional outcome. However, the use of the graft was mainly a second stage after initial debridement.

The use of [SFG] as an acute adjunct for osteosynthesis in osteoporotic or comminuted proximal humeral fractures has been recently advocated aiming at providing immediate structural support preventing later on collapse, varus or loss of reduction. This could be owed to improved loads to failure and initial construct stiffness [15-17]. However, this technique has never been reported for high energy diaphyseal or metaphyseal-diaphyseal humeral fractures. On the contrary, the use of non-vascularized [SFG] has been described for management of humeral diaphyseal nonunion whether aseptic or septic. In a recent study, 17 cases of humeral fracture nonunion treated with plate osteosynthesis and [SFG], union was achieved in 16 patients in an average time of 3.5 months [18].

The use of non- vascularized [SFG] for cases of infected humeral diaphyseal nonunion has been described [19]. The technique was adopted after reaching a plateau status regarding clinical and laboratory evidences of infection following an initial stage of implant removal, radical debridement and administration of proper antibiotic therapy following culture and sensitivity testing. The mean time lag between the debridement and index surgery was 5 months [range; 3-10]. The mean length of the harvested fibula was 13 cm [range; 12-15]. All cases achieved radiological union after a mean period of 5.4 months [range; 4–8]. However, the authors routinely added autogenous cancellous iliac graft to the host graft junctures. This was not our approach in this series; in addition, 3 patients sustained recurrent infection which the authors believed that was related to preoperative inadequate evaluation of infection. In another interesting case series, 6 patients with atrophic nonunion of humeral shaft fractures with osteoporosis have been treated successfully with locked plating and [SFG] [20].

The use of [SFG] is known to be associated with a higher incidence of stress fractures due to the differential uncoupling of osteoblastic bone formation and osteoclastic bone resorption which take place in creeping substitution [21]. However, this is expected to be far less common in the upper limb due to reduced loads. Another well pronounced complication following fibular harvest is the development of valgus ankle deformity which is frequently seen in pediatrics [22]. This could be prevented by the application of tibiofibular syndesmotic screws. The authors of this study have encountered no single case of post-operative valgus ankle deformity.

This study has some defects in the form of small number of patients and lack of comparison with a control group.

Conclusions:

The authors of this study believe that acute application of non-vascularized [SFG] augmenting osteosynthesis in cases of complex high energy humeral fractures both in the open or closed settings provides an efficient tool to enhance fracture reduction, internal fixation and consequently paving the way towards uneventful union.

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