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Comparision of non-vascularized fibular graft as an intramedullary strut v/s conventional bone grafting for management of nonunion of long bones

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Abstract

Objective: The purpose of our study is to describe our experience with the non-vascularised fibular autogenous grafts that was used for the treatment of nonunion of long bones including tibia, femur & humerus and to analyse and compare the results in terms of postoperative wound infection, radiographic evidence of union, postoperative pain and functional disability, success rate of procedure etc. with conventional iliac crest bone grafting and plating, at a tertiary care centre.

Methods: The study was conducted in department of Orthopedics SMSMC, Jaipur from September 2017 to June 2019 and included 80 cases of nonunion of long bone. Amongst these, 40 cases were treated with fibular strut grafting and 40 cases were treated with iliac crest bone grafting, and all cases were followed postoperatively to compare the results in terms of demographic parameters, union time, postop complications.

Result: Amongst 32 cases of nonunion of long bones treated with fibular strut 31 cases (96.9%) showed complete union in mean time interval of 17.77 weeks while only 29 (85.3 %) amongst 34 cases treated with iliac crest bone graft showed union in mean time of 18.41 weeks.

Graft site pain was noted in 20.6% cases of iliac crest graft while no cases of fibular strut graft had this problem; EHL weakness was noted in 34.4% of cases and all of them recovered fully at the end of follow up.

Conclusion: According to our study fibular strut is a better option in treatment of nonunion long bones as maximum cases showed complete union in less time interval and with very few postoperative complications than iliac crest bone grafting.

Keywords: Nonunion, fibular strut, iliac crest bone graft

Introduction

Non-union is a serious complication of fracture. Management of non-union has remained a constant challenge. The associated bone defect, shortening, deformity and infection complicate the management [1]. Non-union is defined by FDA panel as when a minimum of 9 months has elapsed since injury and the fracture shows no visible progressive signs of healing for 3 consecutive months. But the criteria cannot be applied to every fracture. Rather than being limited by a definition of non-union that involves a set of time frame, present day surgeon have come to realize that earlier and more aggressive treatment is warranted. Surgical intervention is usually indicated 3 to 5 months after surgery of fracture which fails to show progressive signs of healing on serial radiography [2]. Of all the fractures of long bones, incidence of non-union is 5 to 10% [3].

Autologous bone grafting has received a negative reputation in the past, mainly due to the high risk of postoperative complications related to the harvesting procedure. However, more recent innovative and minimally invasive harvesting techniques have mitigated the historic issue of donor site morbidity and renewed the interest in autologous bone as a preferred source for bone grafting [4]. The successful treatment of nonunions requires the utilization of numerous resources, especially when infection is concerned. The desired primary treatment outcome of a long bone nonunion is restoration of a functional, painless, well-aligned, infection-free limb. Meticulous soft tissue handling and preservation of the periosteal blood supply in conjunction with rigid fixation are thought to increase union rates and minimize complications [5].

Various methods of treatment have been described for nonunions, including dynamization, reamed exchange intramedullary nailing, compression plating, and percutaneous injection of bone marrow, ultrasound and functional bracing. It has been reported that nonunions with infection, bone loss or both represent a more complex problem and are better managed by poster lateral bone grafting, transfer of the fibula, bone transport, Ilizarov or sometimes amputation. A thorough evaluation of the patient will determine which method is appropriate [6].

Bone graft is a piece of bone implanted in between recipient bones so as to promote the healing of the bone as a result of their components physical properties, namely, an osteoconductive matrix, which act as a scaffold to new bone growth; osteoinductive proteins, which stimulate mitogenesis of undifferentiated cells; and osteogenic cells, which become mineralized to form bone at the site where they are deposited [6]. Autogenous bone graft is regarded as the gold standard because it is not prone to immunological rejection and it has high osteoconductive, osteoinductive and osteogenic properties compared to other types of grafts and graft substitutes. Auto grafts allow faster time to union, lesser needs for revision procedures, and lower infection rate compared to allograft or recombinant morphogenic protein [7].

The reported complications following the use of bone graft are: pain at donor site, infection at the donor site, transmission of infection especially where allograft is used, and fracture at donor site has also been reported [8].

Different surgical situations may call for different types of bone grafting and unique bone graft materials. The bone grafts and bone grafts materials should contain properties which allow them to initiate, stimulate and facilitate bony healing. Amongst all autogenous bone grafts, fibular bone graft is an ideal graft in many circumstances because the vascular inflow can be maintained if needed. A fibular bone graft has excellent strength because of its cortico-cancellous structure [9]. Fibular graft acts as a reliable biological implant for revascularization and its trephine shape adds to the rotational stability.

Nonunions can be subdivided into hypertrophic, oligotrophic, and atrophic types, which guides the needed intervention to achieve healing. Hypertrophic and oligotrophic nonunions are similar in that they have biologic potential, with a blood supply sufficient to allow for healing.

Classification of nonunion [10]

Non unions are classified based on:

- Location:

1) Epiphyseal
2) Metaphyseal
3) Diaphyseal

- Presence or absence of infection: Septic Aseptic
- Etiology:

1) Hypertrophic
2) Oligotrophic
3) Atrophic

- **Pseudarthrosis**

The purpose of our study is to describe our experience with the non-vascularised fibular autogenous grafts and internal fixation that will be used for the reconstruction of posttraumatic tibial, femur, and humeral (long bones) defects and to analyse and compare the results in terms of postoperative wound infection, radiographic evidence of union, postoperative pain and functional disability, osseous resorption, success rate of procedure etc. with conventional iliac crest bone grafting and internal fixation, at a tertiary care centre.

Aims and Objectives

AIM

- The proposed study is aimed to compare the end results of nonvascularized fibular graft as an intermedullary strut and internal fixation with conventional iliac crest bone grafting and internal fixation in nonunion of long bones.

Objectives

- To study the clinical and radiographic evidence of union, post-operative recovery time, functional disability and success rate of procedure.
- To study the donor-site complications of autogenous non vascularized fibula strut graft harvest for non- union of long bones such as postoperative wound infection, postoperative pain.

Materials and Methods

The study was conducted in the Department of Orthopedics SMS Medical College Jaipur, Rajasthan from September 2017 to June 2019 and is a hospital based comparative type of observational study. Patient who attended Department of Orthopedics and accidental emergency SMS hospital Jaipur for treatment of nonunion of long bones were included in the study.

Inclusion criteria

- Patients with established nonunion of long bones.
- Patients who had attained skeletal maturity.
- Patients who had given written informed consent to be included in the study.

Exclusion criteria

- Patients with pathological fractures.
- Patients with uncontrolled systemic comorbidities.

Patients who were diagnosed with Nonunion of long bones were studied for the probable cause of nonunion and who did not have any systemic comorbidity were selected. All patients were randomized to be managed either by conventional iliac crest bone grafting and plating/nailing or for fibular graft as intermedullary strut and plating by method of block randomization using a block of 2, to ensure equal number in each treatment group; after taking consent.

Bone union was defined as no pain and tenderness at the fracture site and union at 3 of the 4 cortices on radiographs.

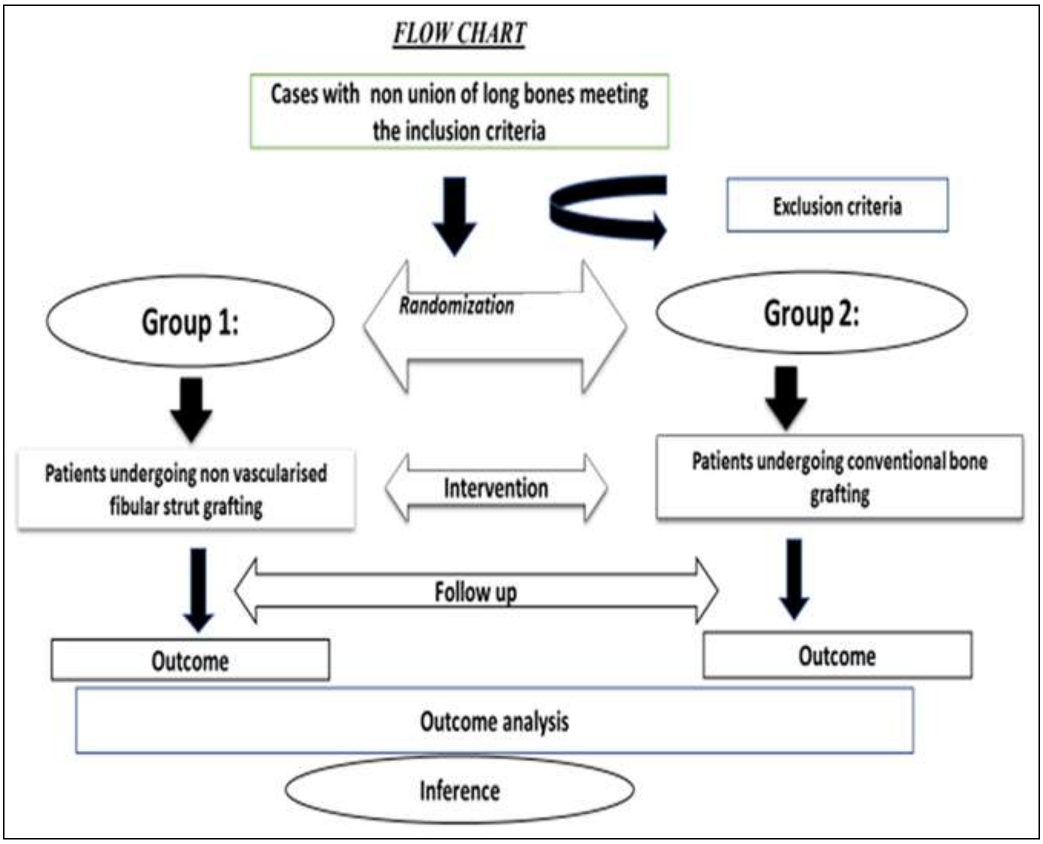
Results were then compared for both the surgeries in terms of union, post- operative recovery time, post op deformities, post op complications, graft site complications etc. Patients were reviewed after discharge for comparing the results of both the surgeries after every 2 weeks till the last follow up.

Nominal/Categorical variables were summarized as frequency and were analyzed using student t test.

- A p value <0.05 was taken as statistically significant.
- All statistical analysis was done using EPI Version 7.2.1.0.

Total 80 patients were taken and divided randomly into two groups by method of block randomization using a block of 2, to ensure equal number in each treatment group. One group including 40 patients was treated with non-vascularized fibular strut bone grafting and implant and the other group was treated with iliac crest bone grafting and implant as treatment. Detailed history was taken including time since initial injury, nature of trauma, mechanism of injury, any associated injury etc and a thorough clinical examination was carried out including general physical and local examination.

Basic lab investigations were done in all patients selected patients underwent preoperative surgical planning, radiological workup and blood investigations. Patients who presented with infection firstly investigated and then were debrided and treated with broad spectrum antibiotics as suggested by culture reports, once infection subsided and ESR and CRP became normal, patients were taken for definitive fixation according to randomization



Surgical technique

Anaesthesia: in the operation theatre GA/spinal anaesthesia /block was given.

Position: Patient was positioned supine on the OT table, scrubbing, painting and drapping was done, torniquette was used if required.

Nonunion site

Skin incision was given generally over the previous scar mark to avoid multiple scar marks subcutaneous tissue was cut, any fibrosis was dissected and muscles were retracted to reach the nonunion fracture site, all the fibrotic tissue was removed between the fractures ends were freshened until the fresh bleeding was seen. The medullary canal was prepared in both fragments. Serial reaming of the proximal and distal fragments was then performed with rigid nail reamers. Bone-holding forceps were used to hold the fragments especially near the fracture site so as to prevent splintering of bone. The length of the fibular graft needed was measured by adding the depth of the last reamer inserted into both fragments.

Fibula graft harvesting

An ipsilateral non-vascularised fibular graft was harvested by a standard technique. Fibula was palpated and a longitudinal skin incision was given at middle 1/3rd of fibula, lower 8-9 cm of fibula was not disturbed to prevent ankle instability.

Subcutaneous tissue was dissected and fibula was separated with the help of periosteum. All care was taken to prevent injury to common peroneal nerve.

Then approximate length (generally 10-12 cm) of fibula was marked, and multiple drill holes were done at proximal and distal ends with the help of drill was done, then fibula was extracted out with the help of osteotome instrument and then wound was thoroughly washed and closure done in layers.

Graft preparation

Then fibular strut surface was cleaned off any tissue. The diameter of the fibular graft was larger than that of the last reamer. An oscillating saw was used to reshape and reduce the diameter of the fibular graft to1 mm less than the last reamer size. The centre of the graft was marked.

Fibula bone grafting

The fibular graft was then inserted into the proximal fragment, with the distal 4 to 5 cm exposed. The distal fragment was reduced onto the fibular graft protruding from the proximal fragment.

Care was taken to avoid fracturing the fibular graft or distal fragment. Once the distal fragment was reduced, the fracture site was distracted. The fibular graft was then pushed into the distal fragment, until the central mark was at the fracture site. Care was taken to apply the fibular graft as soon as possible to keep all the cells viable and contribute in healing process. An appropriate contoured dynamic compression plate was fixed with 4 or 5 bicortical screws proximally and distally.

Iliac crest bone graft

In second group of 40 patients in which iliac crest bone grafting with implant was used as a mode of treatment, nonunion fracture site was exposed in the same manner as above, any intervening fibrous tissue was removed, intramedullary canal was secured and petalling was done around the nonunion fracture site and compression was applied till the graft was harvested from iliac crest.

A pad is applied behind the hip to make iliac crest more prominent.

7- 8cm long incision was made over the iliac crest starting 2cm behind the anterior superior iliac spine, sub cutaneous tissue separated with blunt dissection, periosteum of iliac crest was incised, hemostasis was achieved meticulously. Graft was obtained using osteotome according to amount required, and wound was closed in layers and pressure bandage was applied. The graft was harvested in very thin layers as to increase surface area of contact and promote healing. Then it was placed around the fracture site and appropriate implant was applied to ensure mechanical stability and closure was done in layers. Betadine dressing was applied on the suture site and slab was applied for immobilization.

Postoperative care

Post-operative care in form of broad spectrum antibiotics and periodic change of dressing were done. Drain was applied only in cases of fibular graft cases and not in cases of iliac crest graft, drain was removed after 48 hours and sutures were removed after 2 weeks. The follow-up evaluation consisted of subjective and objective assessment of functional capacity as well as the documentation of any problems associated with either the graft recipient or donar site.

Postoperative care and rehabilitation is done to ensure attainment of satisfactory range of motion in adjacent joints, improve muscle strength as per the site of nonunion. Limb elevation, static quadriceps and hamstring strengthening exercise, active finger/toe movements were advised as a part of above regimen.

Knee bending and shoulder mobilization exercises were started as soon as the postoperative pain subsided to strengthen muscles and prevent joint stiffness, patient was followed every two weeks and evaluated for fracture healing, partial weight bearing was gradually started after 6 weeks depending upon the site and type of nonunion, full weight bearing was started once clinical and radiological union was achieved. Clinical union was defined as no tenderness at fracture site during weight bearing. Radiological union was defined as bridging trabeculation across the fracture site on three out of four cortices.

Observations and Results

The present study was a comparative type of observational study conducted on 80 patients in department of orthopedics SMS Medical College Jaipur. Our aim was to compare the end results of non-vascularized fibular graft as an intermedullary strut and conventional iliac crest bone grafting in nonunion of long bones. We also studied the radiographic evidence of union, postoperative recovery time, functional disability and success rate of procedure and also assessed the donor-site complications of the grafts such as postoperative wound infection, postoperative pain etc.

Table 1: Comparison of Demographic details

Demographic detail	Fibular strut group	Iliac crest group	Total Cases of nonunion
Mean Age (in years)	41.42+/-11.95	41.33+/-13.14	41.38+/-12.42
Gender (M-male %; F –Female %)	M- 80; F-20	M-82.5; F-17.5	M-81.25; F-18.75
Residence (R- Rural%; U- Urban %)	R-67.5; U- 32.5	R-75; U-25	R-71.25; U-28.75
SES (M- middle; P-poor; U-upper)	M-77.5; P-22.5; U-0	M-77.5; P-17.5; U-5	M-77.5; P-20; U-2.5

Table 1 shows the comparison of demographic details between the 2 groups. We found that the mean age of patients with nonunion in our study was 41.38 +/- 12.42 years and 81.25 % of total patients with nonunion of long bones were male while 18.75% patients were female. 71.25% of total patients resided in rural areas and rest in urban region. In our study group 77.5 % patients belonged to middle socioeconomic status, 20% patients were poor and only 2.5% patients belonged to the upper class according to Kuppuswamy classification.

Table 2: Distribution of study subjects according to mode of injury

Mode of injury	Fibular strut		Iliac crest graft		Total	
	N	%	N	%	N	%
Assault	1	2.5	1	2.5	2	2.5
Fall	6	15	5	12.5	11	13.75
RTA	33	82.5	34	85	67	83.75
Total	40	100	40	100	80	100

Chi-square = 0.106 with 2 degrees of freedom; P = 0.948 (NS)

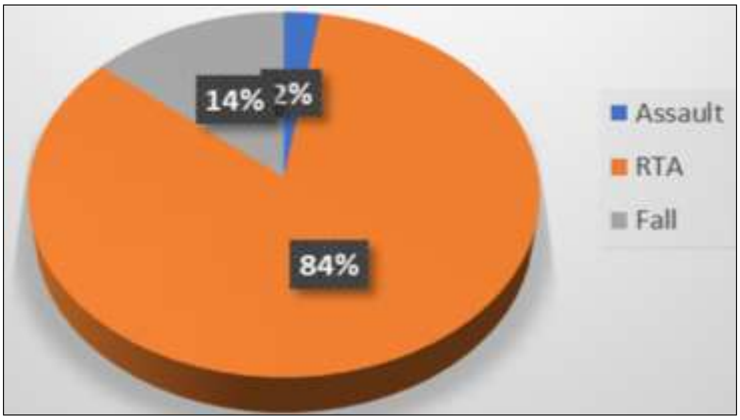


Fig 1: Distribution of cases according to mode of injury

Table 3: Distribution of study subjects according to bone fractured

Bone fractured	Fibular strut		Iliac crest graft		Total	
	N	%	N	%	N	%
Femur	13	33.3	14	35	27	33.75
Humerus	12	30	16	40	28	35
Tibia	15	46.7	10	25	25	31.25
Total	40	100	40	100	80	100

Chi-square = 1.608 with 2 degrees of freedom; P = 0.447 (NS)

Fig 2: Distribution of subjects according to the bone fractured

Table 4: Distribution of study subjects according to segment of individual bones involved in non-union

Site of bone	Femur N (percent)	Humerus N (percent)	Tibia N (percent)
Distal	13 (48.14%)	0 (0%)	14 (56%)
Middle	9 (33.33%)	28 (100%)	11(44%)
Proximal	5 (18.51%)	0 (0%)	0 (0%)
Total	27 (100%)	28 (100%)	25 (100%)

Chi square test = 36.324 with 4 degrees of freedom, p value <0.001 (S)

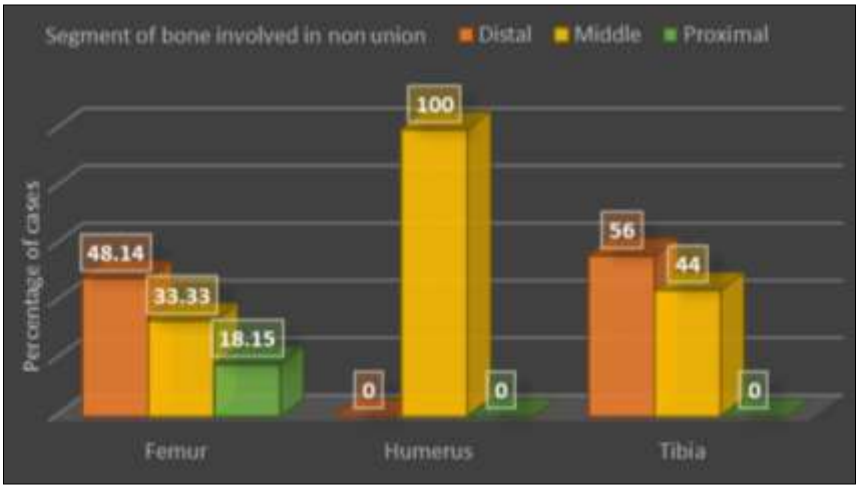


Fig 3: Distribution of study subjects according to segment of individual bones involved

Table 5: Distribution of study subjects according to type of injury

Type of injury	Fibular strut		Iliac crest graft		Total	
	N	%	N	%	N	%
Close	23	57.5	31	77.5	54	67.5
Open	17	42.5	9	22.5	26	32.5
Total	40	100	40	100	80	100

Chi-square = 2.792 with 1 degree of freedom; P = 0.095 (NS)

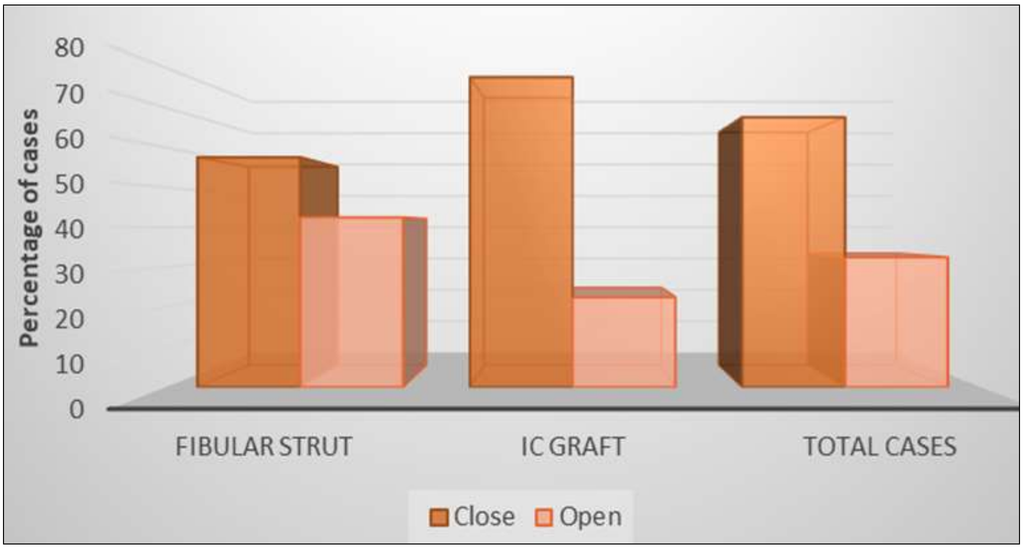


Fig 4: Distribution of study subjects according to type of injury

Table 2 represents that in 83.75% of cases, the mode of injury was road traffic accidents, 13.75% patients had history of fall and only 2.5% patients had history of assault. Table 3 shows that in our study 28 out of 80 cases of nonunion were of humerus, while 27 were of femur and 25 were of tibia. Table 4 shows the relation of segment of individual bones involved in non union. Tibia and femur distal segment were involved most commonly while in humerus all cases had involvement of middle segment. Table 5 shows that 67.5% cases of nonunion sustained closed type of injury while 32.5% cases sustained open injury.

Table 6: Distribution of study subjects according to the type of nonunion

Type of Non union	Total number of cases	Percentage of cases
Gap Non union	48	60
Infected non union	3	3.75
Atrophic	29	36.25
Total	80	100

The above table shows that gap union was present in 60% of cases of nonunion while 36.25% cases had atrophic nonunion. 3.75% cases had infected type nonunion.

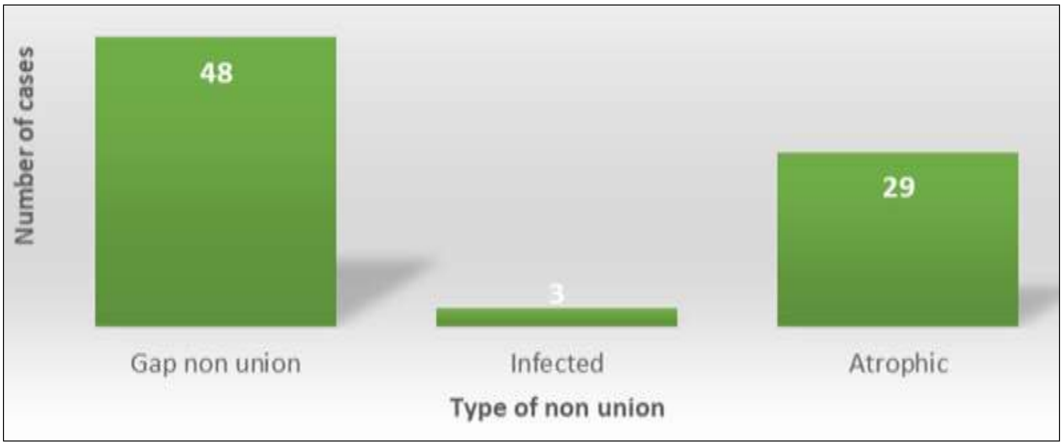


Fig 5: Distribution of study subjects according to type of nonunion

Table 7: Distribution of study subjects according to time from injury to surgery

Months	Fibular strut		Iliac crest graft		Total	
	N	%	N	%	N	%
<10	7	17.5	11	27.5	18	22.5
10-14	27	67.5	23	57.5	50	62.5
15-19	6	15	6	15	12	15
Total	40	100	40	100	80	100

Chi-square = 1.209 with 2 degrees of freedom; P = 0.546 (NS)

In our study we found that 10 to 14 months was the average time interval between injury and treatment of nonunion (surgery) in maximum (62.5%) cases of nonunion.

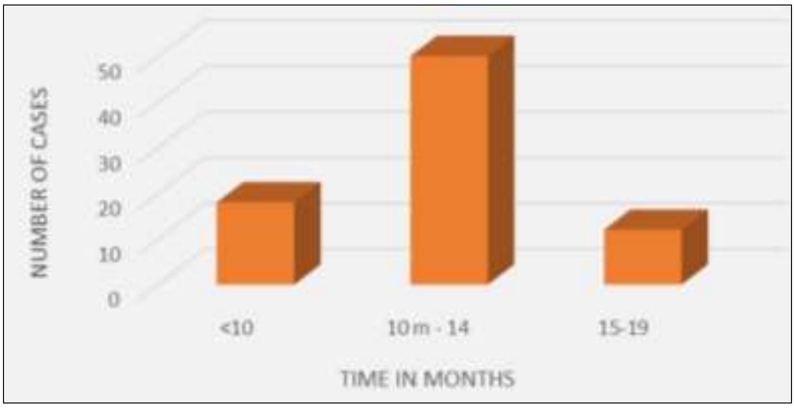


Fig 6: Distribution of cases according to time from injury to surgery

Table 8: Distribution of study subjects according to previous surgeries

Previous surgeries	Fibular strut		Iliac crest graft		Total	
	N	%	N	%	N	%
0	1	2.5	4	10	5	6.25
1	21	52.5	23	57.5	44	55
2	15	37.5	10	25	25	31.25
3	3	7.5	3	7.5	6	7.5
Total	40	100	40	100	80	100

Chi-square = 2.891 with 3 degrees of freedom; P = 0.555 (NS)

The above table shows that 55% cases had undergone surgical procedure once, 31.25% patients twice and 7.5% cases underwent surgical procedure thrice prior to bone grafting while only 6.25% patients did not undergo any prior surgical procedure.

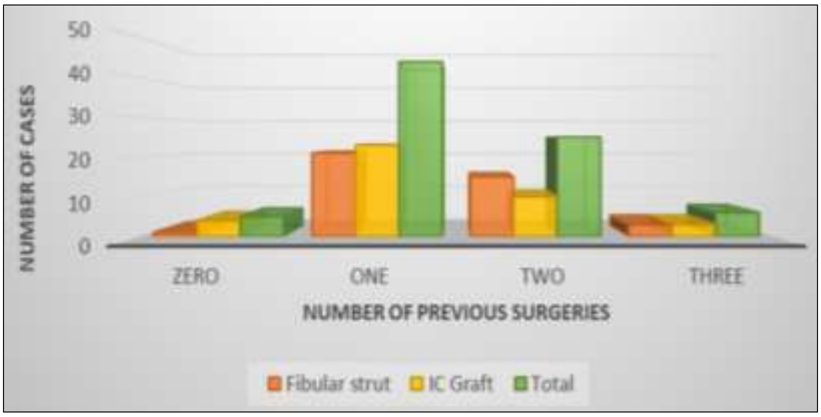


Fig 7: Distribution of subjects according to previous surgeries

Table 9: Comparison of mean graft harvesting time (min) among study groups

Group	N	Mean	Std. Deviation
Fibular strut	40	21.2	3.47
Iliac crest graft	40	21.45	3.71
T-test - t = -0.311 with 78 degrees of freedom; p = 0.757 (ns)			

The above table shows that the mean graft harvesting time for fibular strut was 21.2 minutes with standard deviation of+/- 3.47 minutes while for iliac crest it was 21.45 minutes with standard deviation of +/-3.71 minutes.

Table 10: Distribution of study subjects according to outcome

Outcome	Fibular strut		Iliac crest graft		Total	
	N	%	N	%	N	%
United	31	96.9	29	85.3	60	90.9
Not united	1	3.1	5	14.7	6	9.1
Total	32	100	34	100	66	100

Fisher Exact Test - P = 0.198 (NS).

This table excludes 8 patients from fibular strut group and 5 patients from iliac crest graft group who were lost to follow up.

In our study we found that 96.9% cases of fibular strut showed complete union, while only 85.3% cases of iliac crest bone graft showed union(p value >0.05).

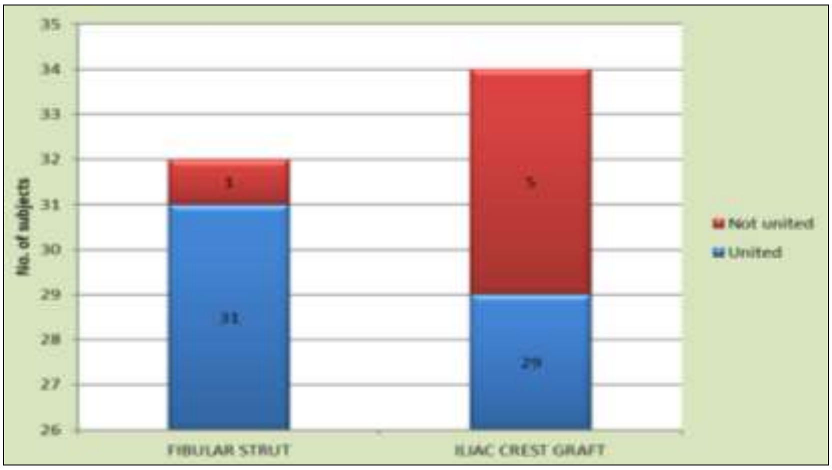


Fig 8: Distribution of study subjects according to outcome

Table 11: Comparison of mean union time (weeks) among study groups

Group	N	Mean	Std. Deviation
Fibular strut	31	17.77	4.67
Iliac crest graft	29	18.41	4.61
T-test - t = -0.533 with 58 degrees of freedom; p = 0.596 (ns)			

This table excludes the patients lost to follow up and patients with nonunion.

In our study we found that the mean time of union in cases of fibular strut graft was 17.77+/-4.67 weeks while cases of iliac crest bone graft united in 18.41 +/-4.61 weeks, though this difference is statistically insignificant (p value>0.05).

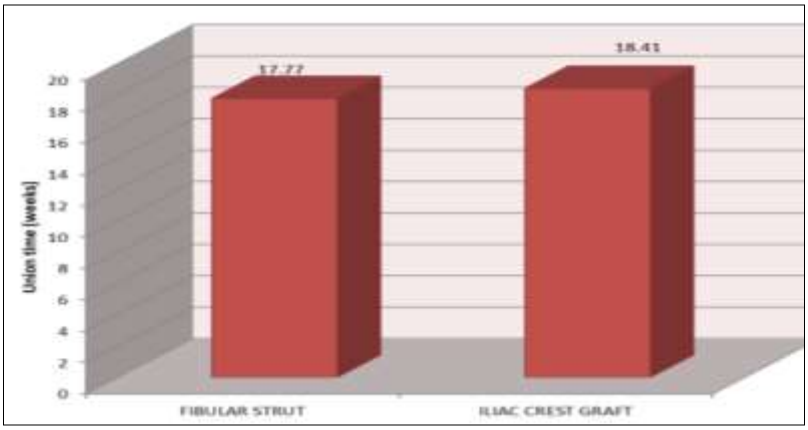


Fig 9: Comparison of mean union time (weeks) among study groups

Table 12: Frequency of complications among study groups

Complication	Fibular strut		Iliac crest graft		P value
	N	%	N	%	
Delayed wound healing	1	3.1	2	5.9	1.000
EHL Weakness	11	34.4	0	0.0	<0.001 (S)
Graft site pain	0	0.0	7	20.6	0.011 (S)
Neuropraxia	3	9.4	5	14.70	0.712
Pain	3	9.4	8	23.5	0.188
Stiff ankle	1	3.1	4	11.8	0.359
Stiff knee	5	15.6	2	5.9	0.251
Stiff shoulder	0	0.0	1	2.9	1.000
Infection	1	3.1	1	2.9	1.000

This table excludes the patients lost to follow up.

The above table compares the common complications noted postoperatively. Graft site pain was present in 20.6% cases of iliac crest graft while no case in fibular strut graft had this problem. This difference is statistically significant (p value <0.05). Extensor hallucis longus weakness was noted in 34.4% cases of fibular strut group.

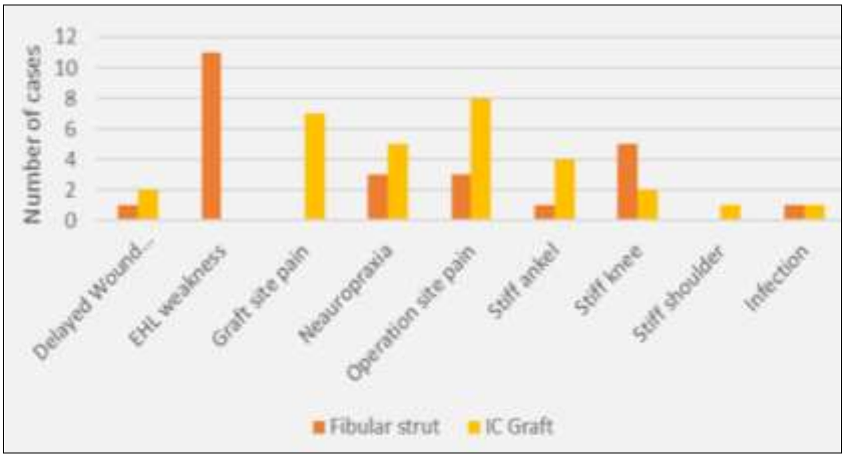


Fig 10: Frequency of complications amongst study groups

Table 13: Distribution of study subjects according to return to normal activity

Return to normal activity	Fibular strut		Iliac crest graft		Total	
	N	%	N	%	N	%
Yes	31	96.9	29	85.3	60	90.9
No	1	3.1	5	14.7	6	9.1
Total	32	100	34	100	66	100

Fisher Exact Test - P = 0.198 (NS)

This table excludes 8 patients from fibular strut group and 5 patients from iliac crest graft group who were lost to follow up.

Above table depicts the comparison of study groups according to the return to their normal activity post operatively. 96.9% of cases in which fibular strut was used were able to get back to their normal activity level in comparison to only 85.3% of cases of the iliac crest graft group (excluding the drop out cases).

Fig 11: Distribution of study subjects according to return to normal activity post operatively

Table 14: Fibular length used in Fibular Strut

Fibular length (cm)	N	%
8	2	5
10	14	35
11	6	15
12	18	45
Total	40	100
Mean ± SD	10.59 ± 1.13 cm	

In our study non vascularized fibular strut was used in 40 cases amongst which in 18 cases, 12cm long fibula was used as intramedullary strut. The average length of fibular graft used was 10.59+/-1.13 cm.

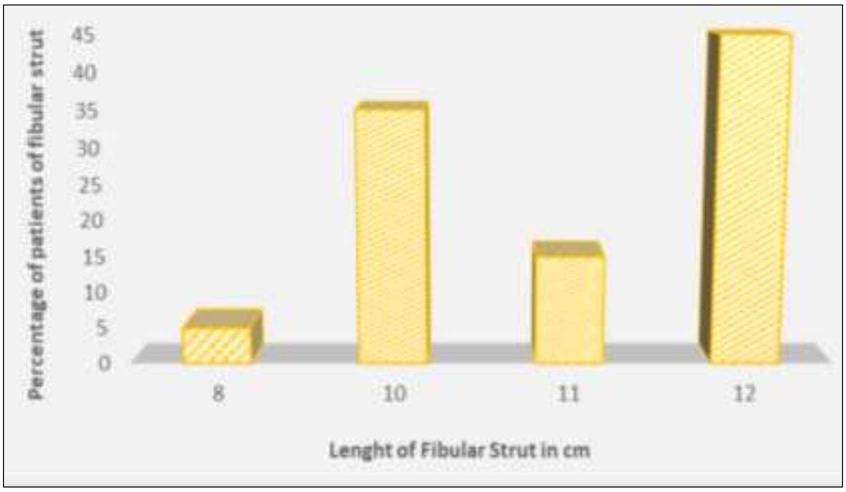


Fig 12: Length of fibular strut used

Table 15: Bone union in relation to addiction habit

Addiction Tobacco/Alcohol/Alcohol+Tobacco	Union		Non-union	
	N	%	N	%
Present	21	35	4	66.66
Absent	39	65	2	33.33
Total	60	100	6	100

Fisher Exact test – P=0.190 (NS)

Above table shows the relation of bone union with addiction habbits. In cases of nonunion about 66.6% patients were addicted to alcohol, tobacco or both, while only 35% patients who showed union had some kind of addiction.

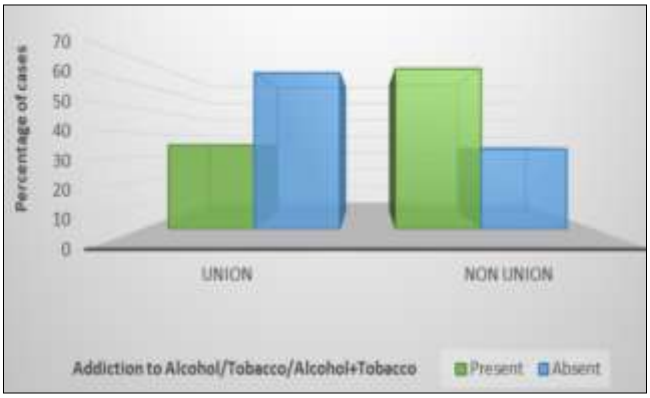


Fig 13: Bone union in relation to addiction hobbit

Discussion

The present study was hospital based comparative type of observational study.

Patient who attended Department of Orthopedics and accidental emergency SMS hospital Jaipur treated for nonunion of long bones. 40 patients were taken in each group (fibular strut group and iliac crest group). Eight patients in fibular strut group and six patients in iliac crest group lost to follow up. Only one patient in fibular strut group and five patients in iliac crest group showed nonunion, which were considered for reevaluation and some different mode of treatment. One patient had preoperative brachial artery and radial nerve injury who underwent neurovascular repair.

- **Sex Incidence**

In our study 81.25% patients of nonunion were male while 18.75% patients were female which is almost similar to the findings of Mustafa Sayed ME *et al.* [11] who noted 91.66% cases were males and 8.33% cases were females, Kedar PP *et al.* [12] and Ramprasad R *et al.* 41 also observed a high percentage of male patients (74.3% and 76%respectvely) in their studies.

The high incidence of nonunion in males could be explained due more exposure of males to high energy force trauma in road traffic accidents as they are more involved in outdoor activities.

- **Age Incidence**

In our study maximum patients belonged to the age group 40-49 years (28.75%) and 22.5% patients aged between 30-39 years and the mean age of patients of nonunion was 41.28+/-12.42 years which is similar to the findings of Deepak RL and Burande VG[2] and Kedar PP[12]. This could be possibly due to the high exposure of patients of age group 30-49 years to outdoor activities and means that maximum patients were young adults who constitute the major work force of population.

- **Residence**

71%patients in our study group belonged to rural background while only 28% were from urban area though our centre is an urban tertiary care centre but the maximum population it deals with resides in rural area.

- **Socioeconomic status**

Our study shows that maximum patients belonged to middle socioeconomic status (77.5%) while only 2.5% patients belonged to upper class according to the Kuppuswamy classification. The possible reason could be the high preference and dependence of middle and lower class families on government institutions like ours.

- **Mode of injury**

In about 83.75% patients the mode of injury was Road traffic accidents, while in 13.75% cases fall from height was the cause. Our findings are in accordance with the findings of Deepak RL and Burande VG[2] study who recorded the similar findings that RTA is the most common mode of injury in a fracture which indicates increased incidence of accidents.

- **Bone fracture incidence**

In our study we found that Humerus followed by Femur were the most common bones affected (35% and 33.75% respectively). Though the difference is statistically insignificant ($p>0.05$)

- **Individual bone segment involved**

Our study shows the relation of segment of individual bones involved in nonunion. Tibia and femur distal segment were involved most commonly while in humerus all cases had involvement of middle segment. Ryzewicz M *et al.* [6] found 59.09% cases of tibial fracture involved distal segment comparative to our findings (56%). The probable explanation to this could be the vicarious blood supply and lack of mascular support in distal tibia. In fractures of Femur in middle and distal 1/3rd segment, nail fixation tends to remain slightly loose in spite of good fixation which contributes to increased chances of nonunion.

- **Type of injury**

67.5% patients of nonunion in our study had close type of injury while the rest had open type of injury. Similar findings were also noted by Deepak RL and Burande VG[2] in their study and they noted that ~60% cases in their study had close type of injury. Kedar PP *et al.* [12] and Vidyadhara S *et al.* [13] also noted higher incidence of close injury (83.33% and 62.85% respectively) in cases and open injury (16.67% and 37.14% respectively) in rest.

- **Type of nonunion**

60% of cases of nonunion while 36.25% cases had atrophic nonunion.3.75% cases had infected type nonunion. Flierl MA *et al.* [4] noticed 30% cases as of atrophic nonunion type while 17% cases in his study were of infected type of nonunion. Ryzewicz M *et al.* [6] found that 41% cases of nonunion in his study were gap nonunion type. These 3 cases of infected nonunion in our study were thoroughly debrided and treated with broad spectrum antibiotics as suggested by culture reports, once infection subsided ESR and CRP became normal patients were taken for definitive fixation.

- **Time from initial injury to definitive treatment**

According to our study, 10-14 months was the average time interval between time to injury and surgery for most of the patients (62.5%), while only 22.5% patients went under definitive corrective surgery in <10 months. Similar to our findings Vidyadhara S *et al.* [13] found an average time interval of 13.33 months between injury and surgery.

Traditional bone setters give tough competition to Orthopedicians which also results in delayed diagnosis and treatment.

- **Number of previous surgery**

Maximum patients in our study had gone under previous one surgery followed by previous two and three surgeries, while very small proportion of patients who did not undergo any surgery previously (managed by conservative methods) were treated for nonunion. These previous surgeries included interlocking nails, plate, external fixators, dynamization, exchange nail etc.

- **Mean graft harvesting time**

The average graft harvesting time for fibular strut was slightly less (21.2 +/-3.47 min) as compared to iliac crest graft (21.45+/- 3.71 min); the difference being statically insignificant (p value 0.75). Salawu ON *et al.* [14] noted an average time of harvesting graft from iliac crest as 18 min.

- **Union rate**

In our study we found superior results in fibular strut group with union rate of 96.9% as compared to 85.3% union rate in the iliac crest group.

Iliac crest bone graft has no mechanical strength to withstand stress prior to nonunion of fracture site and is also associated with quite significant graft site morbidity, fibula transmits 1/8th of body weight (good mechanical strength) and can be useful as vascularized as well as non-vascularized graft for reconstruction of bony defects, non-vascular fibula is easy to harvest with least possible tissue trauma, intramedullary position in addition to load sharing, also helps in bone osteosynthesis [13]. The fibula acts as a filler in the medullary cavity preventing abnormal movement.

- **Mean union time**

We found that mean union time in fibular strut graft group was 17.77+/- 4.77 weeks which is similar to the mean time of 16.75 weeks found by Surender SY [15] in his article on treatment of nonunion of long bones with fibular strut. While the mean union time in iliac crest group was 18.41+/-4.61 weeks similar to our findings Deepak RL and Burande VG[2] in whose study maximum number of patients (72%) showed union within 6 months after using iliac crest bone graft who showed no sings of union at 3 months. Ramprasad R[16] found a mean union time of 9.8 weeks in his work using iliac crest graft for treating nonunion of long bones.

- **Postoperative complications**

In our study we found that delayed wound healing was found in 3.1% cases of fibular group while in 5.9% cases of iliac crest group.

EHL (extensor hallucis long us) weakness was found in 34.4% patients of fibula group postoperatively, which recovered in 100% patients at the end of follow up, it was exclusively seen in fibula graft group because this muscle arises from middle portion of fibula on the anterior surface and interosseous membrane and inserts on dorsal side of the base of distal phalynx of great toe.

Graft site pain was seen exclusively in iliac crest group affecting 20.6% cases, which gradually subsided at the end of follow up.

Sacrifice of the fibula does not appear to have any detectable functional disadvantage.

- **Fibula length**

The average length of fibular strut used as graft material was 10.59 ± 1.13 cm while Gopisankar S *et al.* [17] noted that the mean length of fibular strut used in non union was 13cm (12 to15 cm).

- **Effect of addiction**

In patients of nonunion 66.66% patients were addicted to either alcohol or tobacco or both, while in patients who showed complete union of bone 65 percent of patients did not have any kind of addiction.

Smoking and tobacco chewing deteriorates the general well being of a person and has substantial negative effect on the healing power of the body as it decreases microcirculation around the fracture site.

Conclusion

Free vascularised and non-vascularised fibular grafting provides an attractive option for the reconstructive surgery. Its ability to provide immediate structural support as well as its inherent osteoconductive, osteoinductive and osteogenic properties of fibular grafting should be considered in the management of large segmental bony defects as well as situation in which there has been biological failure of bony healing.

The fibula is easy to harvest and produces less graft site morbidity.

Fibula is probably the most suitable donor bone for reconstruction of defects in a long bone because of its length, geometrical shape, and mechanical strength. Grafts of cortical bone revascularise slowly and incompletely**.**

Iliac crest cancellous bone graft has no mechanical strength to withstand stresses prior to solid union of the fracture site and also is associated with quite significant graft harvest site morbidity. The fibula can be useful as vascularised or non vascularised graft in reconstruction of bony defects. Vascularised bone grafting requires surgical experience and equipment not readily available in every hospital. The technique is demanding of time and resources, and vascular thrombosis may compromise the result.

Nonvascularized grafts do not undergo resorption, therefore, they provide superior strength during the first six weeks. Despite their initial strength, cortical graft still must be supported by internal or external fixation to protect them from fracture. Autologous cortical bone grafts are good choices for segmental defects of bone of > 5 to 6 cm, which require immediate structural support. Larger graft requires prolonged time for resorption and fracture of graft may ensue if osteogenesis is not proper.

The main advantages of autologous cancellous graft are their excellent success rate and low risk of disease transmission. However, disadvantages as cited above include potential morbidity at the donor site, availability in limited quantities, and and risk of wound infection, increased blood loss and prolonged anaesthetic time.

Limitations of study

- Our study was single centre study, had it been a multicentric study, results would have reflected wider range of trauma and nonunion at different trauma centres.
- Sample size of our study was small.
- Follow up period was relatively short

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