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Assessessment of Malrotation after Intramedullary Nailing of Tibial Diaphyseal Fractures in Adults

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Abstract
Background: Intramedullary nailing is the method most commonly used for treatment of tibial diaphyseal fractures. Malrotation or torsion of tibia is one of the complications associated with use of intramedullary nailing. Malrotation, besides presenting problems cosmetically, especially >10^0 can cause knee and ankle arthrosis and other fuctional complications.
Objective: To assess the malrotation following intramedullary nailing in adult patients with tibial diaphyseal fractures.
Study design: The study was a prospective study over a period of one year (1st December 2013 to 30th November 2014) and retrospective study over a period of five years (1st December 2008 to 30th November 2013) conducted in the Department of Orthopaedics, Christian Medical College and Hospital, Ludhiana.
Methodology: Clinico-radiological assessment of all cases (retrospective and prospective) was done after intramedullary nailing. CT images of bilateral tibia was used to quantify accurately the degree of tibial rotation. The CT images will include a number of axial cuts (usually 2 or 3) taken 2 mm apart just above the proximal tibiofibular joint and just proximal to the tibiotalar articulation. The images of proximal and distal cuts was captured on a single film.
Results: Intra operative method of fracture reduction, supine on table leg partially flexed is superior for rotational control.It is better to have external rotational deformity than internal rotation deformity. So if we have to err we can err on the external rotation side.

***Keywords**: CT scan, Intramedullary nailing, Malrotation, Tibial diaphyseal fractures*

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I. Introduction

INTRODUCTION

Fracture of the tibia diaphysis is the most common long bone fracture encountered by the orthopaedic surgeons in their daily practice. This is because the bone is subcutaneous and does not have much protection from the surrounding muscle.[1] they usually occur in young and active patients and are often due to high-energy trauma like motor vehicle accidents, sports or falls from height. Direct trauma like road traffic accidents often cause concomitant severe soft tissue damage with a high incidence of open fractures.[2] The lack of soft tissue covering of the tibial shaft and difficult blood supply make these fractures vulnerable to infection and non-union.[3]

Over the years various modalities of treatment both operative and non-operative has been used. The goal of treatment in tibial diaphyseal fractures is to attain rapid union with acceptable axial and rotational alignment, while preserving initial bone length.[4] Operative treatment with standardized protocols is common, as in conservative treatment due to a long period of immobilization chances of deep venous thrombosis, compartment syndrome, soft tissue injury and chronic regional pain syndrome are very high. Also casting is associated with the highest incidence of delayed union, nonunion and malunion.[5] Several different operative options and implants are available. Intramedullary (IM) nailing is the most common method of fixation of most tibial fractures.[6] Intramedullary nailing provides a huge biomechanical stability and unreamed intramedullary nails can be used even in higher degrees of soft tissue injury up to grade IIIb if wound closure or plastic flap done within 48 hours.[7]

Closed interlocking nailing helps in faster healing of fractures because the fracture haematoma and also the periosteal callus formation are not disturbed. Several studies have shown that tibial nailing is associated with superior outcome and less complications compared to those obtained with open reduction and internal fixation

(ORIF) / external fixation, or even non-operative treatment in unstable fractures.[8,9] A potentially serious, but often underappreciated complication intramedullary nailing for diaphyseal fractures is rotational malrotation. Besides presenting problems cosmetically, torsional deformities may lead to lower extremity arthrosis and other functional complications.[10-15]

Tibial torsion is the anatomical twist of the proximal versus distal articular axis of the tibia bone in the transverse plane around the longitudinal axis.[16, 17] Any change in the tibial torsion, either in the internal or in the external direction, is considered a malrotation and is occasionally seen after fixation of the tibial shaft fractures by closed IM nailing.[9, 18] Various clinical, anthropometric and radiological methods have been used to determine tibial torsion. Measurements of tibial torsion are difficult. Clinical measurements give only approximate values.[19-21] Conventional radiographic methods are complex and have only limited reliability.[21] Rotational malalignment after IM tibial nailing is rarely specifically addressed and most clinical studies have measured axial malalignment using plain radiography. There is not enough accurate information about the incidence and severity of tibial malrotation after IM nailing.[9, 16, 17] During recent years, different techniques based on computed tomography (CT) have been described.[17, 22]

In many studies, tibial malrotation has been measured clinically and the incidence is reported to be 0-6% [23] whereas such incidence is reported to be 22-36% by using other measurement methods such as computerized tomography (CT) scanning.[9,18] To date, several methods have been described to measure tibial torsion and CT scan is the investigation of choice with good inter- and intra-observer reliability and repeatability.[9] The purpose of this study was to determine the incidence and severity of tibial malrotation using CT scan in a consecutive series of patients who underwent closed reamed IM nailing for diaphyseal fractures. To our knowledge, there is only one similar previous study that has assessed tibial malrotation in a consecutive series of patients.[9]

II. Materials And Methods

MATERIALS AND METHODS

The study was conducted in the Department of Orthopedics at Christian Medical College and Hospital, Ludhiana. It was a hospital based, 1 year prospective (1st December 2013 to 30th November 2014) and five year retrospective study (1st December 2008 to 30th November 2013) and included 61 patients with tibial shaft fractures treated with intramedullary nail. Patients of 18 years and above who underwent intramedullary nailing for isolated tibia fractures between December 2008 to November 20014 were deemed eligible. Total of 101 patients were enrolled according to the inclusion and exclusion criteria in the study, out of which 40 retrospective patients did not turn up for evaluation. 61 patients consented to be part of the study. Out of the 61, 9 could not complete the CT scan (out of 9 patients 3 refused due to radiation exposure and 6 could not undergo CT scan due to the costs involved). 4 patients were lost to follow up. Out of remaining 48 patients, 36 were prospective and 12 were retrospective cases. The patients were explained about the study and written informed consent was obtained.

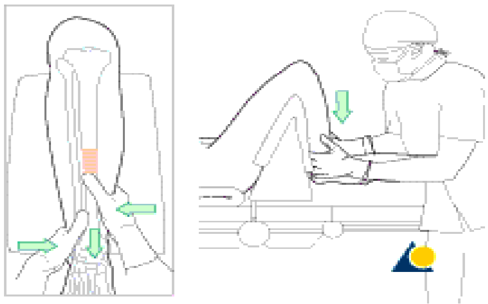
INCLUSION CRITERIA

All adult (>18 years of age) patients with unilateral fracture shaft tibia admitted in the department of orthopaedics treated with intramedullary nailing during the study period.

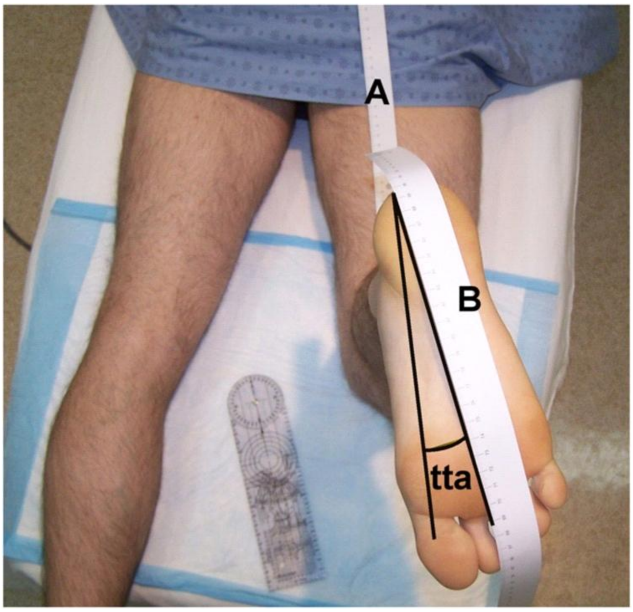
EXCLUSION CRITERIA

- Patients less than 18 years of age
- Metaphyseal fractures of tibia
- Previous ipsilateral tibial fracture
- Bilateral fracture shaft tibia
- Ipsilateral proximal or distal tibial fractures
- Fractures extending to knee or ankle joints

For retrospective cases patients hospital records were verified, the pre and post op x rays of intramedullary nailing of tibia were reviewed. Patients were contacted through mobile phone and explained about the study. At the visit to hospital demographic data, fracture characteristics, and treatment history were collected of all these patients and entered on master sheet. Clinical assessment as well as CT scan was done after taking informed consent. LEFS scoring was also done for these patients. For prospective cases all patients who underwent intramedullary nailing after admission to CMC within the stipulated time were taken. During Intramedullary nailing reduction of fracture done by leg partially flexed on table or by leg off the table. CT scan was done post-operatively and the patients were followed up for minimum 6 months with clinical assessment, LEFS score. The angles for roatational malallignement were calculated by comparing with the opposite limb on post-operative CT scan. Prospective data were entered in the master sheet for evaluation. Two methods of reduction used in present study were leg off the radiolucent table and leg partially flexed and on table. During traction, reduction is controlled by palpating the tibial crest.



Clinical assessment: Patients were asked to lie prone, with knees flexed at 90 degrees and ankle in neutral position. With the use of a goniometer, the longitudinal axis of the thigh was compared with longitudinal axis of foot(fig 1). Rotation was recorded for both lower limbs.[20]



Radiologic assessment: CT scan were carried out using a Spiral CT scanner (Philips inguinity 128 slice CT scanner).CT images of bilateral tibia were used to quantify accurately the degree of tibial rotation based on a standard technique similar to those previously described in the literature.[17, 22] This involved positioning the patient in the supine position with minimum movement during scanning. Proximal and distal transverse axes were determined with CT scanning (Fig 1). The CT images included a number of axial cuts (usually 2 or 3) taken 2 mm apart just above the proximal tibiofibular joint and just proximal to the tibiotalar articulation. The proximal reference line (line P) was determined by drawing a line tangent to the dorsal border of the tibia on the image captured just proximal to the fibular head. The distal reference line (line D) will be determined by the transverse axis through the distal tibia that passes through the center of the fibula and tibia on a slice just above the distal tibial plafond. Tibial torsion was defined as the angle between the perpendiculars lines to the two reference lines. The contralateral limb were used as a control to the affected limb. Internal rotation deformity were assigned a negative value and external rotation were given a positive value with zero representing the calculated torsion of the normal or unaffected tibia.

From references in previous literature [9, 15] and for the purposes of this study, we defined significant malrotation as a rotational difference of greater than 10° compared with the normal limb. The images of proximal and distal cuts were captured on a single film.

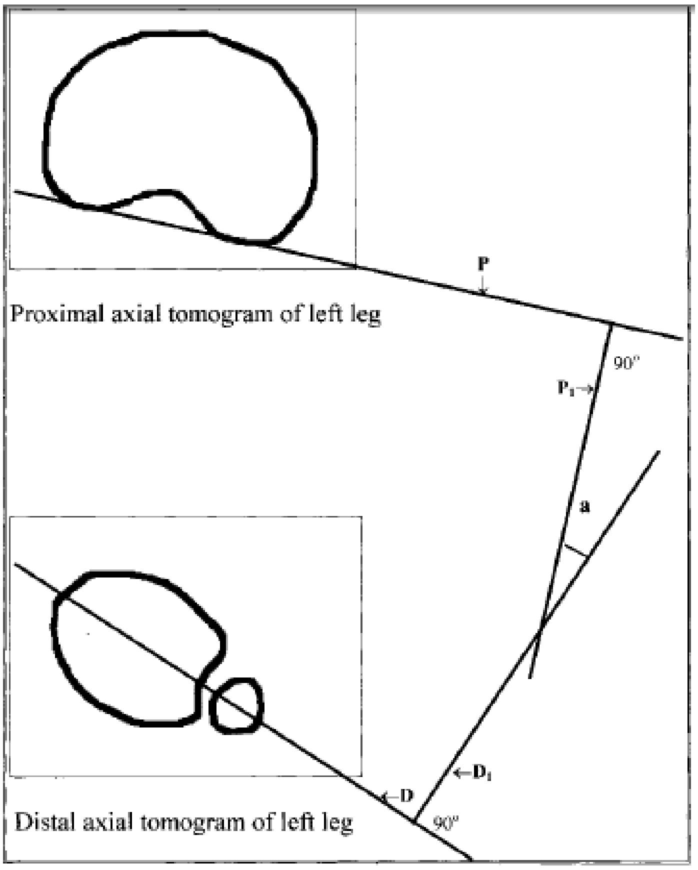


Figure 1

Calculation of torsional angle: Two perpendiculars P1 & D1 were drawn from the proximal reference line (P) and the distal reference line (D) in such a manner that they intersected within the confines of the film. Angle '*a'* was geometrically equal to the tibial torsion.

Functional outcome of lower extremity were measured at follow-ups of 6 months or after by lower extremity functional scale (LEFS – ANNEXURE 1). LEFS focused specifically on the level of difficulty one had, or perceived having, with the completion of a number of specific activities. It consisted of twenty activity related items, each with a maximum score of 4 points. Items were rated on a 5 point scale ranging from 0 to 4. The highest total score of 80 points indicated a high functional level. The minimum clinically important difference was 9 points. The one point questionnaire was filled by most patients in less than two minutes and was scored by tallying the responses for all of the items.

Statistical method: The overall incidence of malrotation was then calculated by using appropriate statistical techniques and correlated.

Data were entered in Microsoft excel and analyzed in SPSSversion16 for windows. Frequencies and proportions were calculated. Chi square test and fisher exact were the test of significance. P value less than 0.05 was taken as significant.

III. Result And Analysis

The study was conducted in the Department of Orthopedics at Christian Medical College and Hospital, Ludhiana. It was a hospital based, 1 year prospective (1st December 2013 to 30th November 2014) and five year retrospective study (1st December 2008 to 30th November 2013). Patients of 18 years and above who underwent intramedullary nailing for isolated tibia fractures between December 2009 to November 20014 were deemed eligible. Total of 102 patients were enrolled in the study out of which 38 were prospective and 64 were retrospective. Out of 38 prospective, 2 patients were lost to follow up. Out of the 64 retrospective patients 40 patients did not turn up for evaluation. Out of the remaining 24 patients 3 refused CT scan due to radiation exposure, 9 refused due to the costs involved. 12 retrospective cases completed the CT scan as per protocol. So Out of remaining 48 patients, 36 were prospective and 12 were retrospective cases. The prospective cases were followed up for minimum of 6 months. Both prospective and retrospective cases were evaluated as per the protocol.

The age range of patient is from 18 to 72 years with a mean of 34.90±12.15. (Table1)

Males formed the dominant group (83.3%) as compared to females (16.67%). (Table2)
Majority of the injuries were due to road traffic accidents (RTA) 40(83.3%), followed by fall from height 6 (12.50%) and few were due to alleged assault 2 (4.17%). (Table3)
Majority of the subjects 30 (62.50%) had a fracture of the right tibia, while 18 (37.50%) subjects had fracture of the left tibia. (Table4)
According to the AO classification 42A fractures were the most common, out of which most common subtype was 42A2, followed by 42B, out of which 42B2 was the most common subtype. In type 42C fractures only 42C2 subtype was noted in the present study. (Table5)
According to the Gustilo & Anderson grading majority 37(77.08%) fractures were closed or open grade 1 fractures, followed by open grade 2 & open grade 3B,5each(10.42%),followed by open grade 3B,1(2.08%).(Table6)
4 (8.33%) patients had fracture of the proximal $1/3^{rd}$ of tibia while 22 (45.83%) patients had fracture of the mid $1/3^{rd}$ and 22 (45.83%) had fractures of the distal $1/3^{rd}$ of the tibia. (distal and mid $1/3^{rd}$ were more commonly preferred for imil nailing). (Table7)
The level of fibula fracture was almost equal in frequency in the proximal, mid and lower $1/3^{rd}$. The segmental fractures were less common. (Table8)
Intra-op method of reducing fracture in a supine position partially flexing the limb was more common in 40 (83.33%) as compared to leg off the table in 8(16.67%) cases. (Table9)
As per clinical assessment malrotation of less than 10^o is more common 31(64.58%) as compared to malrotation of greater or equal to 10 degrees 17(35.42%). (Table10)
On CT evaluation 5 (10.42%) patients had no malrotation as compared to opposite limb. 29(60.42%) patients had malrotation of <10 degrees. 14(29.17%) patients had malrotation ≥ 10 degrees. (Table11)
Internal rotation malreduction was more commonly seen as compared to external rotation. (Table12)
AO fracture had no relationship with degree of post-operative malrotaion. (Table13)
Open grade 1 fractures were effectively managed as closed fractures, hence have been clubbed together. Open grade 2, 3A and 3B were treated by open reduction. The degree of malrotation of <10 degrees and ≥ 10 degrees had no correlation with the open reduction or closed reduction methods. (Table14)
Based on the location of fracture the mid $1/3^{rd}$ fractures and distal $1/3^{rd}$ had a very low percentage of malrotation <10degrees (75%), though this was not statistically significant. (Table15)
Based on the location of fracture the proximal $1/3^{rd}$ fractures had a high percentage of malrotation ≥10 degrees (75%) as compared to distal $1/3^{rd}$ (18.18%).This was statistically significant with P value of 0.047. (Table16)
Based on the location of fracture the proximal $1/3^{rd}$ fractures had a high percentage of malrotation ≥10 degrees (75%) as compared to mid $1/3^{rd}$ (31.82%), though this was not statistically significant.(Table17)
The side of the leg involved had no relationship to the degree of post-operative malrotation. (Table18)
There was no significant relationship between level of fibula fracture and post-operative malrotation. (Table19)
The external malrotation group had less chance of malrotation of ≥10 degrees (21.43%). This data was statiscally significant with P value of 0.0325.The internal malrotation group did not have a significant difference in number of cases in <10 degrees and ≥10 degrees. (Table20)
There was no relationship between the modes of injury with post-operative malrotation. (Table21)
The intra-operative method of fracture reduction with the leg off the table caused greater 6(75%) chances of malrotation of ≥10 degrees as compared to reduction technique of keeping patient supine with leg partially flexed 8(20%) of ≥10 degrees. This was statistically significant with P value 0.005. (Table22)
We did not find any significant relationship, whether surgery was done ≤3 days or >3 days after the injury. (Table23)
The mean LEFS score of 48 patients was 71.9. (Table24)
LEFS value had no relationship with age of the patient in years.(Table25)
LEFS value had no significant relationship with the method of fracture reduction. (Table26)
Patients with malrotation had less lower extremity functional (LEFS) score of 71.58±2.74 as compared to patients with no malrotaion deformity 74.6±2.79. The P value was clinically significant with value of 0.023. (Table27)
Patients with internal malrotation had less lower extremity functional (LEFS) score of 71.1±2.48 as compared to patient's external malrotaion deformity 72.57±3.08. The P value was clinically significant with value of 0.05. (Table28)
Patients with malrotation ≥10 degrees have had lesser LEFS score of 68.86±1.41 as compared to patients with <10 degrees 73.15±2.34. The P value was clinically significant with value of 0.001. (Table29)

IV. Discussion

The study was conducted in the Department of Orthopedics at Christian Medical College and Hospital, Ludhiana. It was a hospital based, 1 year prospective (1st December 2013 to 30th November 2014) and five year retrospective study (1st December 2008 to 30th November 2013) and included 48 patients with tibial shaft fractures treated with intramedullary nail. 36 prospective and 12 retrospective cases were included in the study.

Distribution according to Age

Study	Year	Mean age in years(range)
Puloski et al	2004	34(17-67)
Jafarinejad et al	2012	33.4(17-67)
Theriault et al	2012	37.1(18-65)
Present study	2015	34.9(18-72)

In the present study the mean age was 34.9 years and with a range of 18 to 72 years. The maximum number of patients were in 26-35 years age group(29.17%) followed by those between 18-25 years age group(27.08%), followed by those between 36-45 years (25.00%). The mean age of the present study is approximately same as the studies done by Puloski et al (2004), Jafarinejad et al (2012) and slightly less than as done by Theriault et al (2012). Higher incidence in younger age group can be attributed the fact that most injuries were caused by road traffic accidents.

Distribution according to Gender

STUDY	YEAR	MALES NUMBER(INCIDENCE)	FEMALE NUMBER(INCIDENCED)
Puloski et al	2004	18(81.81%)	4(18.18%)
Jafarinejad et al	2012	53(88.33%)	7(11.66%)
Present study	2015	40(83.33%)	8(16.67%)

In the present study there were 40 (83.33 %) males and 8 (16.67%) females. This is similar to study conducted by Puloski et al (2004) and Jafarinejad et al (2012). This may also be attributed to the fact that the major cause of tibial shaft fractures was road traffic accident, possibly correlating with males forming the predominant group in the study.

Distribution of mechanism of injury

Study	Year	RTA	Fall	Assault
Jafarinejad et al	2012	51(85%)	7 (11.66%)	2(3.33%)
Present study	2015	40(83.3%)	6(12.50%)	2(4.17%)

Road traffic accident (RTA) form the major cause of injury in our study 40(83.3%), fall from height form the second major group 6(12.50%), and followed by assault 2(4.17%). This is similar to the data obtained from the study by Jafainejad et al (2012) where road traffic accounted for the major group 51(85%). Usually high velocity force is needed to fracture shaft possibly correlating to fact that road traffic accident is the major cause.

Distribution according to AO fracture classification

study	YEAR	AO type A	TYPE B	TYPE C
Prasad et al	1999	8(36.36%)	8(36.36%)	6(27.28%)
Puloski et al	2004	13(59.09%)	7(31.82%)	2(09.09%)
Jafarinejad et al	2012	30(50.00%)	21(35.00%)	9(15.00%)
Present study	2015	25(52,08%)	16(33.34%)	7(14.58%)

In our study most common fracture according to AO classification is type A 25(52.08%), followed by type B 16(33.33%) and then type C7(14.58%). This is similar to the data obtained from the study by Puloski et al (2004) and Jafainejad et al (2012) where AO type A was most common followed by type B and then type C.

Distribution according to the side involved

Study	Year	Right tibia	Left tibia
Prasad et al	1999	14(63.63%)	8(36.36%)
Jafarinejad et al	2012	32(53.33%)	28(46.66%)
Present study	2015	30(62.50%)	18(37.50%)

In present study right sided tibia involvement was seen in 30 (62.50%) as compared to left side involvement in 18(37.50%). This is similar to the data obtained from the study by Prasad et al (1999) for right tibia 14(63.63%) followed by 8(36.36%) for left tibia. Jafarinejad et al (2012) also showed the right side 32(53.33%) and left side (46,67%).This suggests that right side fracture of tibia is more common.

Distribution according to Open/Closed fracture

Study	Year	Open			Closed
Puloski et al	2004	4(18.19%)	Grade 1	2	18(81.81%)
			Grade 2	1	
			Grade 3A	0	
			Grade 3B	1	
Jafarinejad et al	2012	0(0%)			60(100%)
Present study	2015	19(39.58%)	Grade 1	8	29(60.42%)
			Grade 2	5	
			Grade 3A	1	
			Grade 3B	5	

In the present study majority of fractures 29(60.42%) were closed and 19(39.58%) were open fractures of various grades. This was similar to study conducted by Puloski et al(1999) where closed fractures formed the major group 18(81.18%) followed by 4 (18.19%). Study conducted by Jafarinejad et al(2012) included only closed fractures.

Distribution according to location of fracture

Study	Year	Proximal 1/3rd	Middle 11/3rd	Distal 1/3rd	Segmental
Puloski et al	2004	1(4.54%)	12(54.54%)	9(40.90%)	0
Jafarinejad et al	2012	5 (8.33%)	42(70,00%)	13(21.66%)	0
Present study	2015	4(8.33%)	22 (45.83%)	22 (45.83%)	0

Middle 1/3rd and distal 1/3rd fractures are the most common in our study 22 each (45.83%), followed by proximal 4(8.33%). This is similar to study conducted by Puloski et al (2004) where middle 1/3rd 12(54.54) was the commonest followed by distal 1/3rd 9(40.90%). Middle 1/3rd fractures are also the most common in study conducted by Jafarienejad (2012) accounting for 42 cases (70%)

Distribution of degree of malrotation(CT scan)

Study	**Year**	**No. of pts**	**No rotation (0 degrees)**	**CT malrotation**	
				<10 degrees	≥ 10 degrees
Prasad et al	1999	22	1(4.54%)	15(68.18%)	6(27.27%)
Puloski et al	2004	22	0 (0%)	17(77.27 %)	5(22.63%)
Jafarinejad et al	2012	60	0 (0%)	42(70%)	18(30%)
Theriault et al	2012	70	0 (0%)	41(58.57%)	29(41.42%)
Present study	2015	48	5(10.42%)	29(60.42%)	14(29.17%)

Theiault et al (2012) used CT scan and reported incidence of malrotation of less than 10 degrees in 41 (58.57%) and malrotation of >=10 degrees in (41.42%). This was comparable to our study where we observed malrotation of less than 10 degrees in 29 (60.42%) and malrotation of >=10 degrees in14 (29.17%), and no rotational deformity was seen in 5(10.42%).Prasad et al(1999) reported malrotation of less than 10 degrees in 15 (71.42%) and malrotation of ≥10 degrees in (28.58%). Puloski et al(2004) reported malrotation of less than 10 degrees in 17 (77.27%) and malrotation of ≥10 degrees in (22.63%). Similarly Jafarinejad et al (2012) reported malrotation of less than 10 degrees in 42 (70.00%) and malrotation of >=10 degrees in (30.00%).

Frequency of degree of malrotation(Clinical)

Study	**Year**	**No.of pts**	**No rotation**	**Clinical malrotation**	
				<10 degrees	≥10 degrees
Theriault et al	2012	70	0	43(61.42%)	27(38.58%)
Present study	2015	48	0	31(64.58%)	17(35.42%)

Theiault et al (2012) in their study have reported clinically, incidence of malrotation of less than 10 degrees in 43 (61.42%) and malrotation of ≥10 degrees in 27 (38.58%) which was comparable to our study. In present study malrotation of less than 10 degrees in 31 (64.58%) and malrotation of ≥10 degrees in17 (35.42%) was noted.

Frequency of External malrotation/Internal malrotation or no malrotaion

Study	Year	Total no. of patients	External malrotation	Internal malrotation	No rotation
Parasad et al	1999	22(100.00%)	10(45.45%)	11(50.00%)	1(4.54%)
Theriault et al	2012	29(100.00%)	24(82.75%)	5 (17.24%)	0(0%)
Present study	2012	48(100.00%)	14(29.16%)	29(60.41%)	5(10.41%)

Theiault et al (2012) in their study on CT scan, reported incidence of external rotation in 24(82.75%) and internal rotation in 5(17.24%) patients with no roatation noted in none. Prasad et al(1999) reported almost equal frequency for both with 11(50.00%) in internal malrotation and 10(45.45%) in external roatation with one patient having no rotation(4.54%).In present study internal rotation was more common 29(60.41%) as compared to external rotation 14(29.16%). Five (10.41%) patients had no malrotaion.

Frequency of ≥ 10 degrees of external/internal malrotation

Study	Year	≥10 degrees	
		External malrotation	Internal malrotation
Theriault et al	2012	24(82.75%)	5(17.24%)
Present study	2015	3 (21.42%)	11(78.57%)

Theiault et al (2012) in their study have reported on CT scan, incidence of external malrotation of ≥ 10 degrees in 24(82.75%) and internal malrotation of ≥ 10 degrees in 5(17.24%) patients. In present study internal malrotation of ≥ 10 degrees was more common 11(78.57%) as compared to external malrotation 3(21.42%).

Relationship of location of fracture (distal1/3rd &proximal 1/3rd) with Degree of radiological malrotation as per CT scan

Based on the location of fracture the proximal 1/3rd fractures had a high percentage of malrotation ≥10 degrees (75%) as compared to distal 1/3rd (18.18%).This was statistically significant with P value of 0.047. This suggests that there are more chances of malrotation of ≥ 10 degrees in the proximal 1/3rd fractures. This could be due to more muscle mass at the proximal site which leads to more swelling, also the shin of tibia is not present in the proximal 1/3rd of shaft to control the rotation. We suggest on should prefer alternative methods such as plating for proximal1/3rd tibial shaft fractures.

We could not find any literature on correlation of degree of malrotation(<10 degrees or ≥ 10 degrees) with level of fracture.

Correlation of method of reduction with Radiological malrotation

The method of fracture reduction intra-op of leg off the table caused greater 6(75%) malrotation of ≥10 degrees as compared to reduction technique of keeping patient supine with leg partially flexed 8(20%) of ≥10 degrees. The correlation is significant with P value 0.005.

We could not find any literature on correlation on degree of malrotation(<10 degrees or ≥ 10 degrees) with intra-op method of fracture reduction.

Correlation of LEFS score with degree of malrotation(CT scan)

Study	Year	LEFS		P value
		Malrotation <10	Malrotation ≥10	
Theriault et al	2012	72.6±8.7	70.08± 8.6	0.41
Present study	2015	73.15±2.34	68.86±1.41	<0.001

Theiault et al (2012) study on LEFS score and degree of malrotation (<10 degrees or ≥10 degrees) reported mean LEFS score of 72.6 in patients with < 10 degrees of malrotation and mean LEFS score of 70.08 in ≥ 10 degrees of malrotation. In present study mean LEFS score of 73.15 in patients with < 10 degrees of malrotation and mean LEFS score of 68.86 in ≥ 10 degrees of malrotation, which was statistically significant with P value of <0.001. This correlates that patients with ≥10 degrees of malroation had poorer functional outcome as compared to those with less than < 10 malrotation

Correlation of LEFS Score with Malroation or No Malrotation

In the present study patients with malrotation had less lower extremity functional (LEFS) score of 71.58±2.74 as compared to patients with no malrotaion deformity 74.6±2.79. The P value was statistically significant with value of 0.023. This suggests that patients with malroation had poorer functional outcome as compared to those with no malrotation.

We could not find any literature on correlation of LEFS score with malroation or no malrotation.

Correlation of LEFS Score with External Malroation or Internal Malrotation

In the present study, patients with internal malrotation had less lower extremity functional (LEFS) score of 71.1±2.48 as compared to patients with external malrotaion 72.57±3.08. The study was statistically significant with P value of 0.05. This implies that patients with internal malroation had poorer functional outcome as compared to those with external malrotation.

We could not find any literature on correlation of LEFS score with external malroation or internal malrotation.

V. Tables And Graphs

Table: 1 Distribution according to Age

	Frequency	Percentage
1) 18-25	13	27.08%
2) 26-35	14	29.17%
3) 36-45	12	25.00%
4) 46-55	8	16.67%
5) >55	1	2.08%
Total	48	100.00%

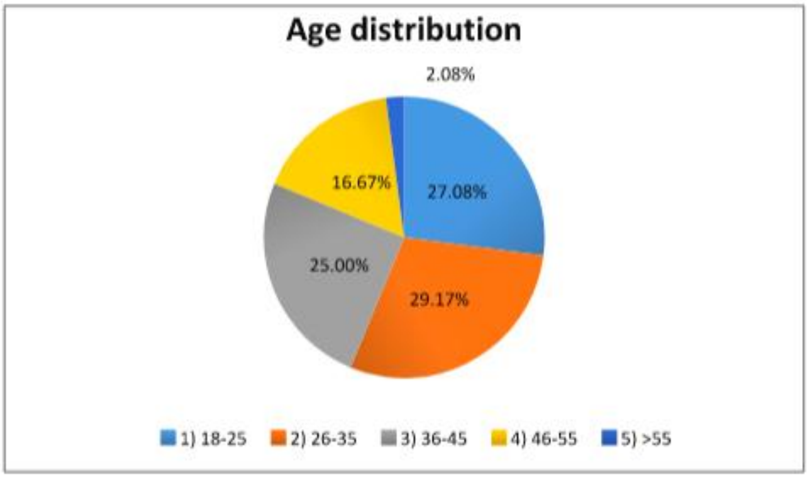


Table: 2 Gender distribution

	Frequency	Percentage
Female	8	16.67%
Male	40	83.33%
Total	48	100.00%

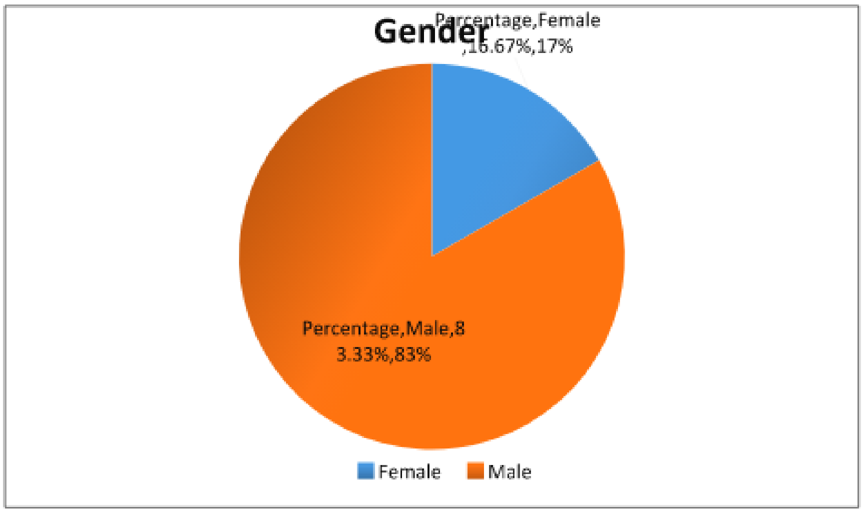


Table: 3 Distribution of mechanism of injury

	Frequency	Percentage
RTA	40	83.33%
Fall	6	12.50%
Assault	2	4.17%
Total	48	100.00%

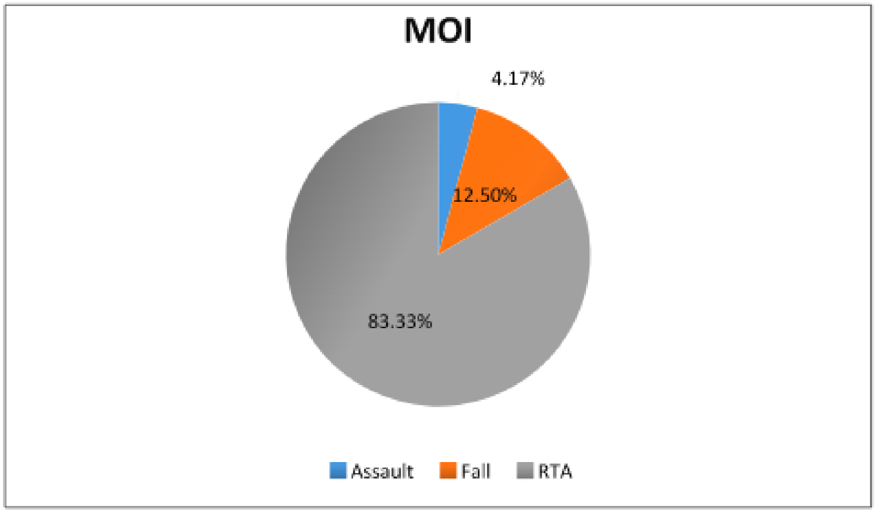


Table: 4 Distribution according to the side involved

	Frequency	Percentage
Left	18	37.50%
Right	30	62.50%
Total	48	100.00%

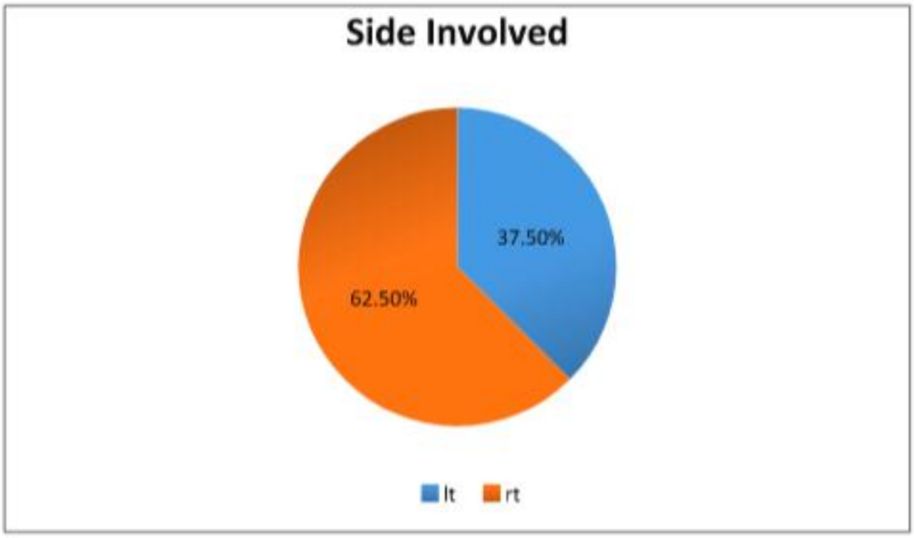


Table: 5 Distribution according to AO fracture classification

AO classification		Frequency	Percentage
42A		25	52.08%
A	42A1	(1)	(2.08%)
	42A2	(18)	(37.50%)
	42A3	(6)	(12.50%)
42B		16	33.33%
B	42B1	(1)	(2.08%)
	42B2	(11)	(22.92%)
	42B3	(4)	(8.33%)
42C		7	14.58%
C	42CI	(0)	(0%)
	42C2	(7)	(14.58%)
	42C3	(0)	(0%)
Total		48	100%

Table: 6 Distribution according to Open/Closed fracture

	Frequency	Percentage
Closed/Open grade 1	37	77.08%
Open grade 2 Open grade 3A Open grade 3B	5 1 5	10.42% 2.08% 10.42%
Total	48	100.00%

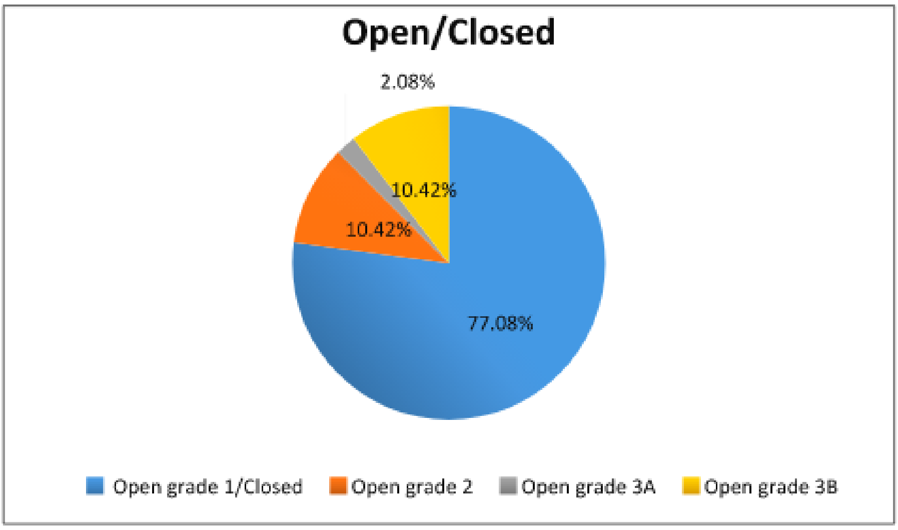


Table: 7 Distribution according to location of fracture

Location	Frequency	Percentage
Proximal 1/3rd	4	8.33%
Mid 1/3rd	22	45.83%
Distal 1/3rd	22	45.83%
Total	48	100.00%

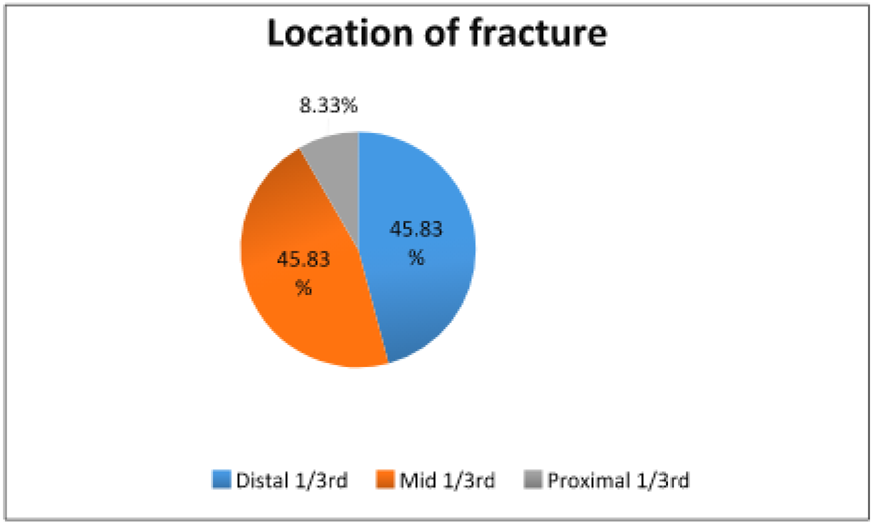


Table: 8 Distribution according to location of fibula fracture

Location	Frequency	Percentage
Distal 1/3rd	15	31.25%
Mid 1/3rd	16	33.33%
Proximal 1/3rd	14	29.17%
Segmental	3	6.25%
Total	48	100.00%

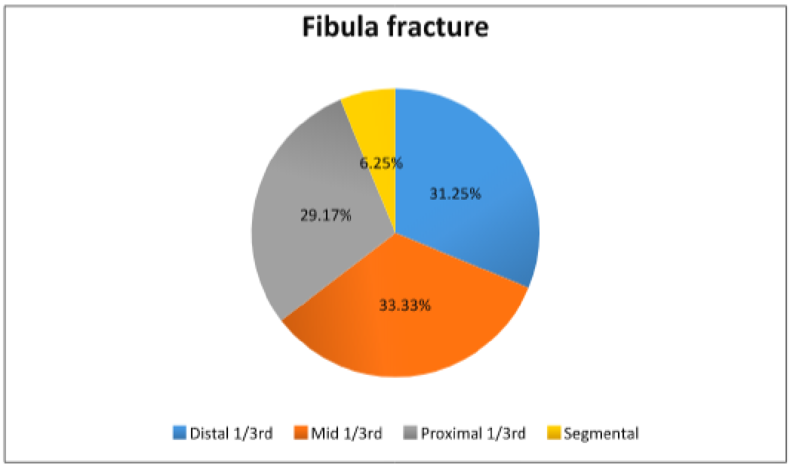


Table: 9 Reduction technique

	Frequency	Percentage
Leg off table	8	16.67%
Supine partially flexed	40	83.33%
Total	48	100.00%

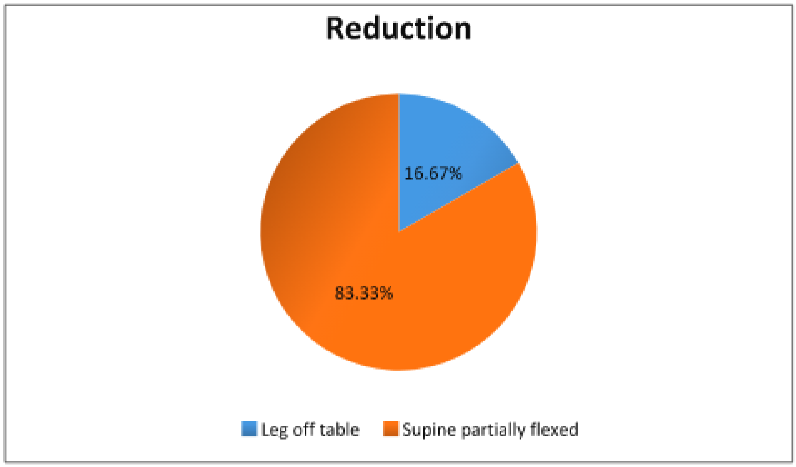


Table: 10 Distribution of Clinical malrotation

	Frequency	Percentage
1) <10 degree	31	64.58%
2) ≥10 degree	17	35.42%
Total	48	100.00%

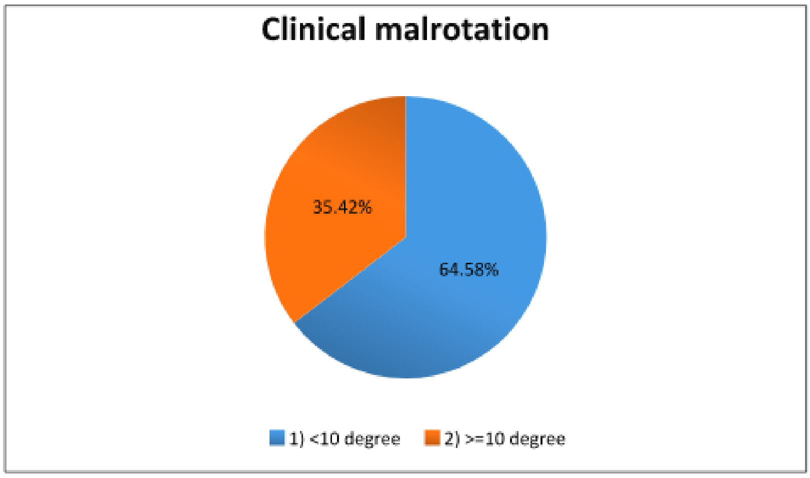


Table: 11 Distribution of radiological malrotation as per CT

CT scan malrotation	Frequency	Percentage
• 0 degree	5	10.42%
• <10 degree	29	60.42%
• ≥10 degree	14	29.17%
Total	48	100.00%

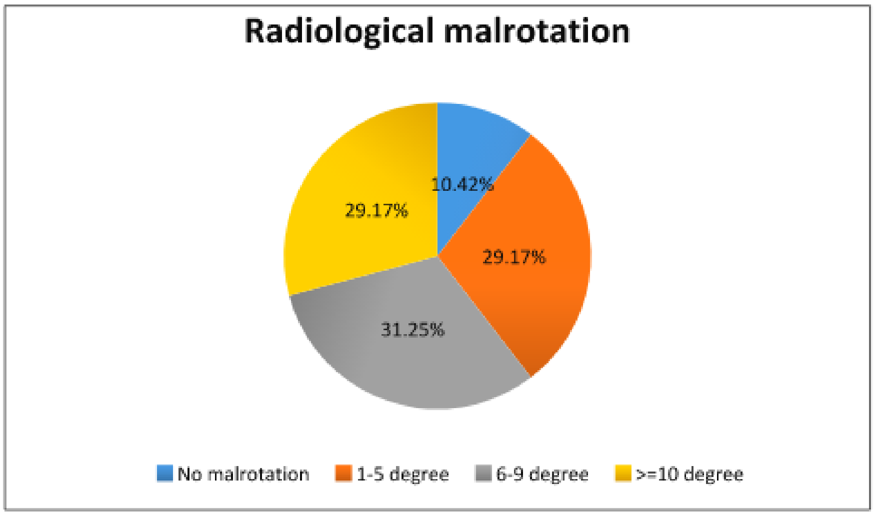


Table: 12 Distribution of Internal/External Mal rotation

	Frequency	Percentage
External Malrotation	14	32.55%
Internal Malrotation	29	67.44%
Total	43	100.00%

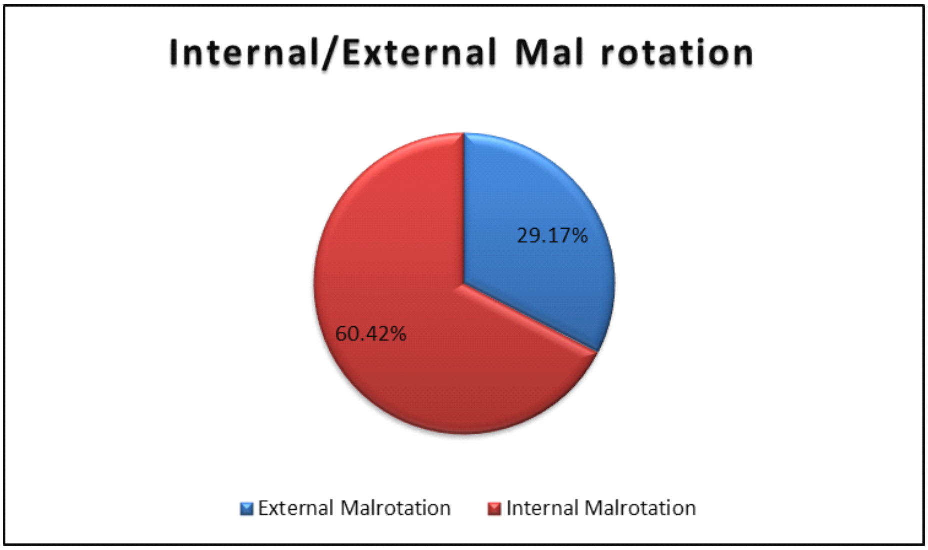


Table: 13 AO type * Radiological malrotation

		Radiological malrotation			
		1) <10 degree	2) ≥10 degree	Total	P value
AO type	42A1	1(100.00%)	0 (0.00%)	1 (100.00%)	0.977
	42A2	13(72.22%)	5 (27.78%)	18(100.00%)	
	42A3	4 (66.67%)	2 (33.33%)	6 (100.00%)	
	42B1	1(100.00%)	0 (0.00%)	1 (100.00%)	
	42B2	7 (63.64%)	4 (36.36%)	11(100.00%)	
	42B3	3 (75.00%)	1 (25.00%)	4 (100.00%)	
	42C2	5 (71.43%)	2 (28.57%)	7 (100.00%)	
Total		34(70.83%)	14(29.17%)	48(100.00%)	

$\chi 2=1.201$
df=6

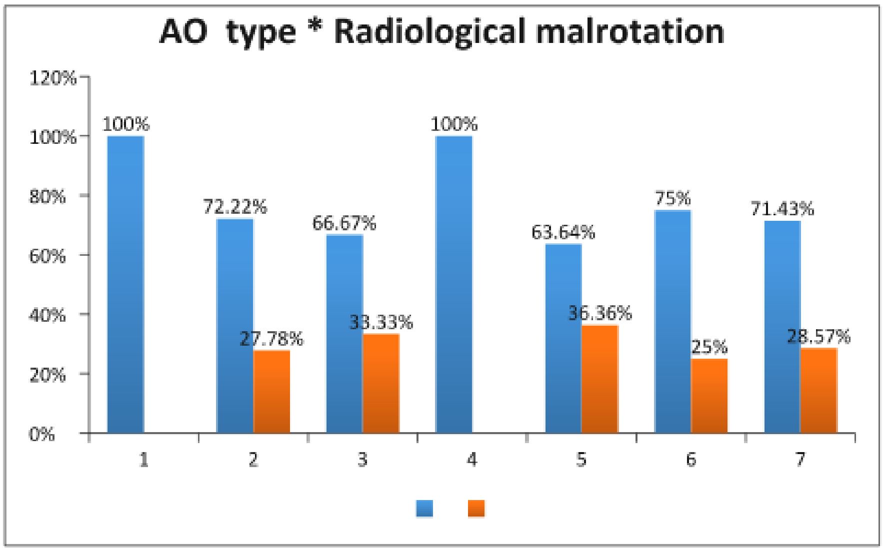


Table: 14 Open/Closed * Radiological malrotation

Type of fracture		Radiological malrotation		Total	P value
		1) <10 degree	2) ≥10 degree		
Open/Closed	Open(grade 2,3A,3B)	9(81.82%)	2 (18.18%)	11(100.00%)	0.469
	Closed/Open grade 1	25(67.57%)	12(32.43%)	37(100.00%)	
Total		34(70.83%)	14(29.17%)	48(100.00%)	

x^2=2.117
df=1

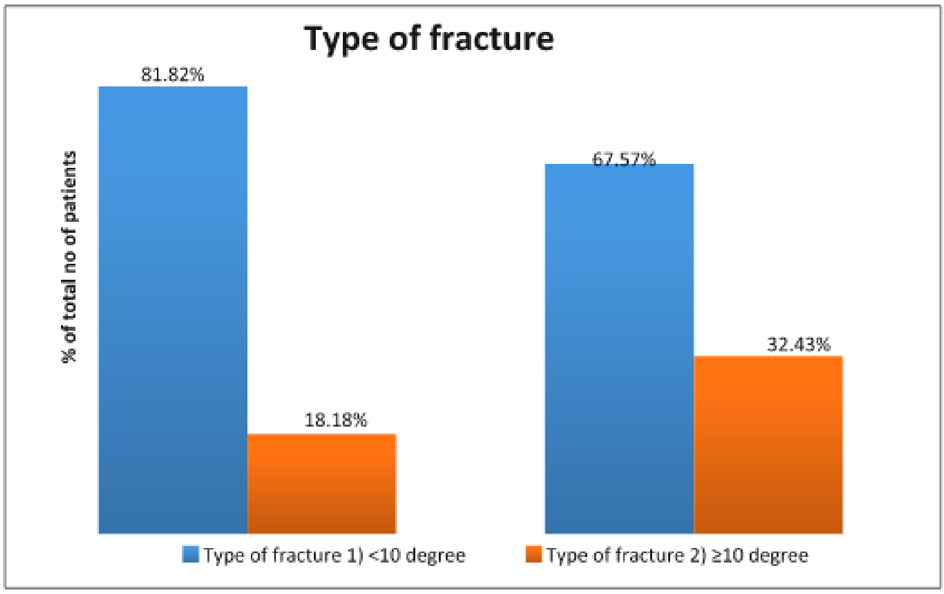


Table: 15 Correlation of location of fracture (mid1/3rd &distal1/3rd) with Radiological malrotation

		Radiological malrotation		Total	P value
		1) <10 degree	2) ≥10 degree		
Location of fracture	Distal 1/3rd	18 (81.82%)	4 (18.18%)	22 (100.00%)	0.488
	Mid 1/3rd	15 (68.18%)	7 (31.82%)	22 (100.00%)	
Total		33(75%)	11(25%)	44(100.00%)	

Fisher exact test

Table: 16 Correlation of location of fracture (distal1/3rd &proximal 1/3rd) with Radiological malrotation

		Radiological malrotation		Total	P value
		1) <10 degree	2) ≥10 degree		
Location of fracture	Distal 1/3rd	18 (81.82%)	4 (18.18%)	22 (100.00%)	0.047
	Proximal 1/3rd	1 (25.00%)	3 (75.00%)	4 (100.00%)	
Total		19(73.08%)	7(26.92%)	26(100.00%)	

Fisher exact test

Table: 17 Correlation of location of fracture (mid 1/3rd &proximal 1/3rd) with Radiological malrotation

		Radiological malrotation		Total	P value
		1) <10 degree	2) ≥10 degree		
Location of fracture	Mid 1/3rd	15 (68.18%)	7 (31.82%)	22 (100.00%)	0.264
	Proximal 1/3rd	1 (25.00%)	3 (75.00%)	4 (100.00%)	
Total		16(61.54%)	10(38.46%)	26(100.00%)	

Fisher exact test

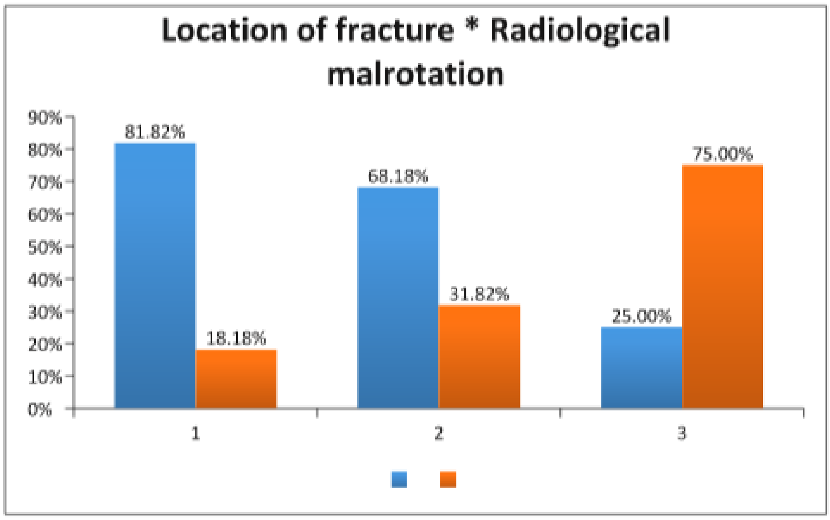


Table: 18 Correlation of the side Involved *with radiological malrotation

		Radiological malrotation		Total	P value
		1) <10 degree	2) ≥10 degree		
Side Involved	Left	11(61.11%)	7 (38.89%)	18(100.00%)	0.251
	Right	23(76.67%)	7 (23.33%)	30(100.00%)	
Total		34(70.83%)	14(29.17%)	48(100.00%)	
$\chi 2$=1.318					
df=1					

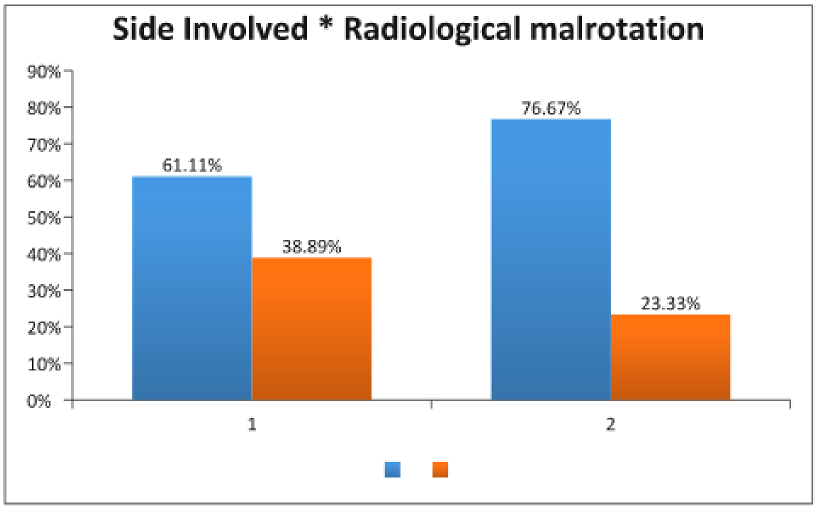


Table: 19 Correlation of fibula fracture with radiological malrotation

		Radiological malrotation		Total	P value
		1) <10 degree	2) ≥10 degree		
Fibula fracture	Distal 1/3rd	11(73.33%)	4 (26.67%)	15(100.00%)	0.536
	Mid 1/3rd	13(81.25%)	3 (18.75%)	16(100.00%)	
	Proximal 1/3rd	8 (57.14%)	6 (42.86%)	14(100.00%)	
	Segmental	2 (66.67%)	1 (33.33%)	3 (100.00%)	
Total		34(70.83%)	14(29.17%)	48(100.00%)	
$\chi2$=2.181					
df=3					

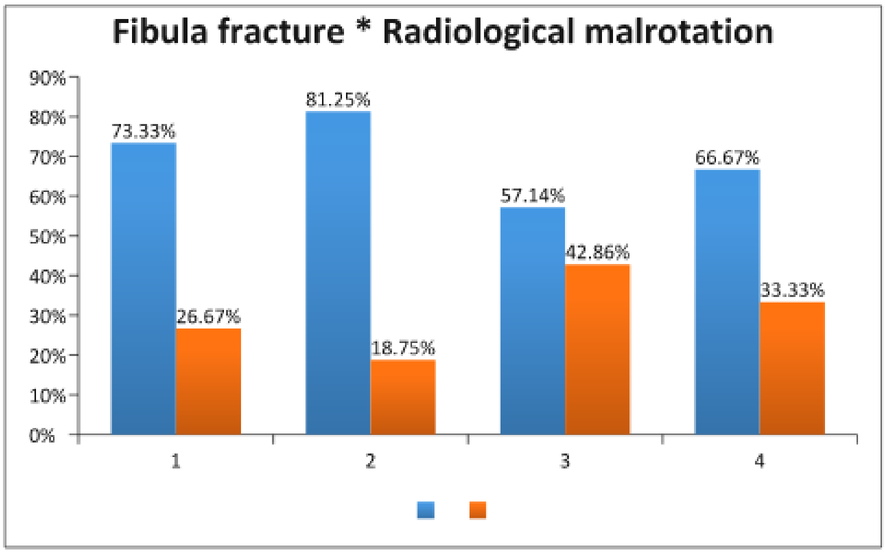


Table: 20 External/Internal Rotation * Radiological malrotation

	Radiological malrotation		Total	P value
	1)<10 degree	2) ≥10 degree		
External rotation	11(78.57%)	3(21.43%)	14(100%)	0.0325
Internal rotation	18(62.07%)	11(37.93%)	29(100%)	0.1936

Fisher exact test

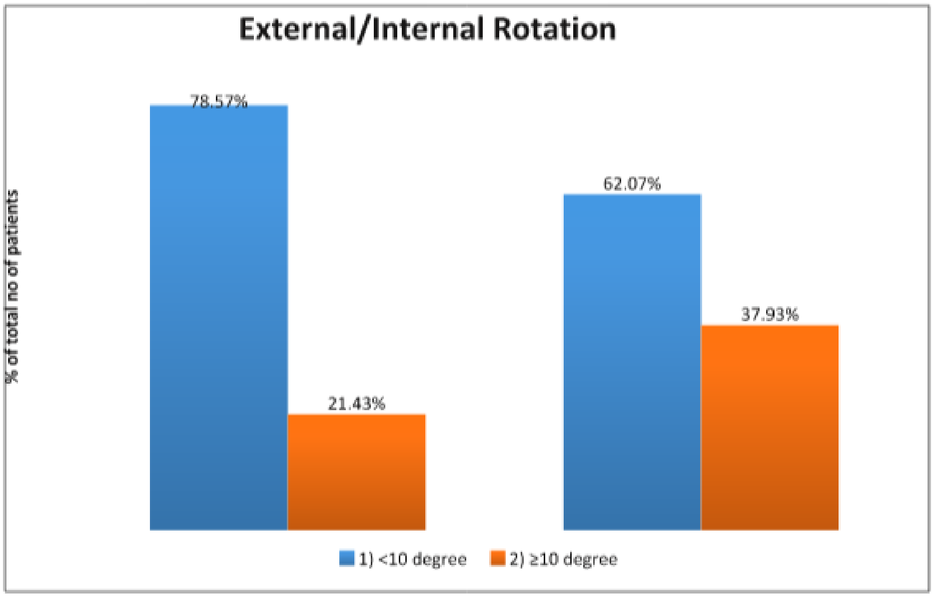


Table: 21 Correlation of mechanism of injury with Radiological malrotation

		Radiological malrotation			
		1) <10 degree	2) ≥10 degree	Total	P value
MOI	Assault	2(100.00%)	0 (0.00%)	2(100.00%)	0.642
	Fall	4(66.67%)	2 (33.33%)	6(100.00%)	
	RTA	28(70.00%)	12(30.00%)	40(100.00%)	
Total		34(70.83%)	14(29.17%)	48(100.00%)	

$\chi 2=.887$
df=2

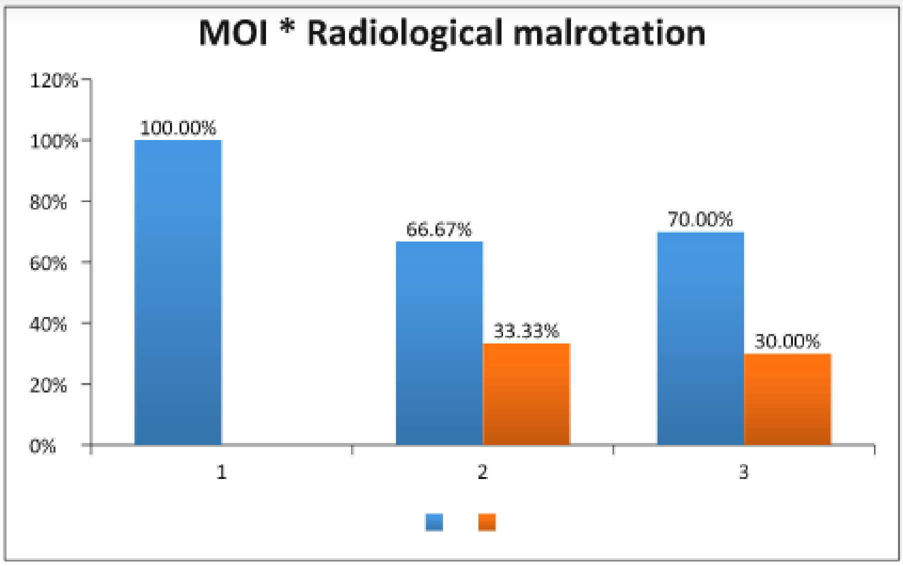


Table: 22 Reduction * Radiological malrotation

		Radiological malrotation			
		1) <10 degree	2) ≥10 degree	Total	P value
Reduction	Leg off table	2(25.00%)	6(75.00%)	8 (100.00%)	0.005
	Supine partially flexed	32(80.00%)	8(20.00%)	40(100.00%)	
Total		34(70.83%)	14(29.17%)	48(100.00%)	

Fisher exact test

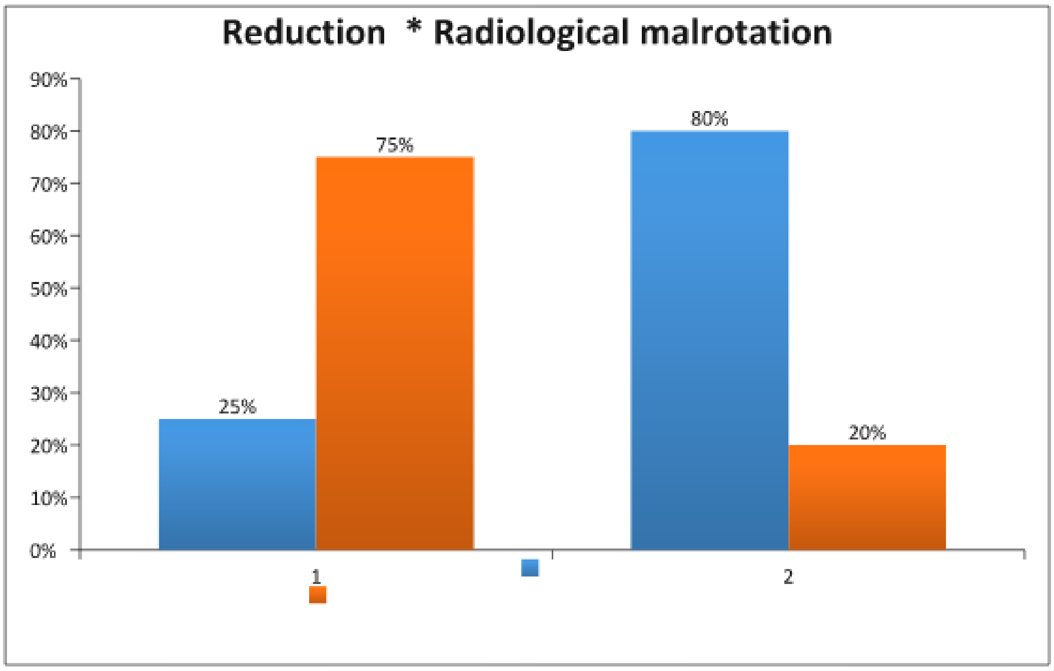


Table: 23 Surgery days after injury vs. malrotation

		Radiological malrotation		Total	P value
		<10 degree	≥10 degree		
Surg days after injury	1) ≤3	20 (71.43%)	8 (28.57%)	28 (100.00%)	0.915
	2) >3	14 (70.00%)	6 (30.00%)	20 (100.00%)	
Total		34 (70.83%)	14 (29.17%)	48 (100.00%)	

x^2=0.012
df=1

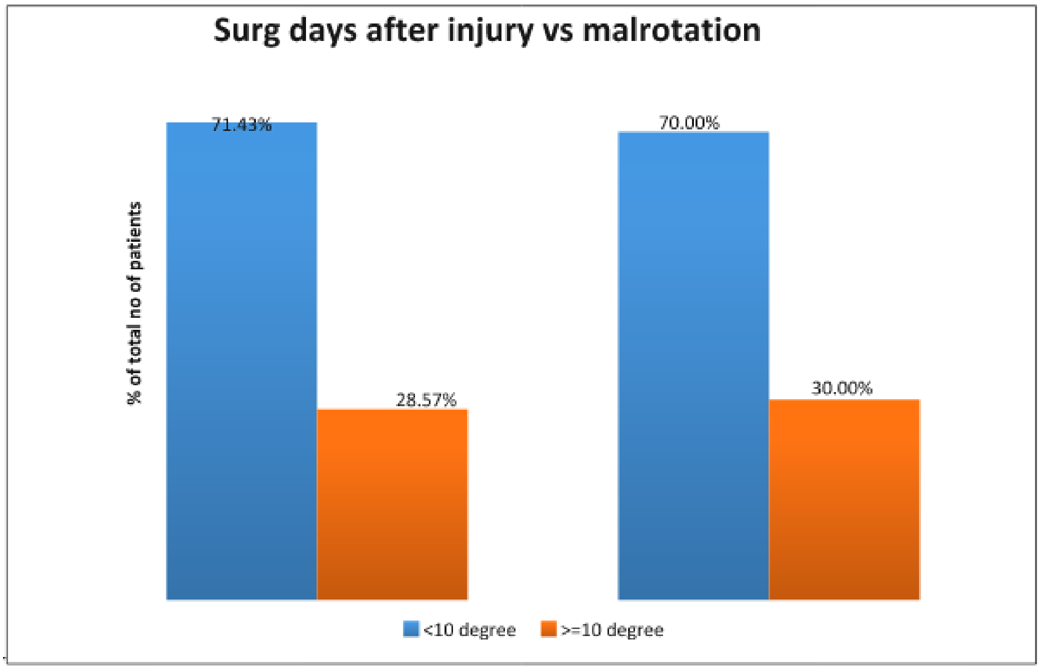


Table: 24 LEFS score

	Sample size	Mean ± SD	Median	Min-Max	Inter quartile Range
LEFS Score	48	71.9 ± 2.88	72	65-77	69.500 - 74.000

Table: 25 Correlation of LEFS Score with Age

	18-25	26-35	36-45	46-55	>55	P value
LEFS Score						.894
Sample size	13	14	12	8	1	
Mean ± SD	72 ± 2.94	71.86 ± 3.08	72.17 ± 2.04	71.75 ± 3.88	69 ± 0	
Median	72	73	72	72.5	69	
Min-Max	68-77	66-75	69-76	65-76	69-69	
Inter quartile Range	69 - 75	69 – 75	70.500 - 74	69 - 75	69 – 69	

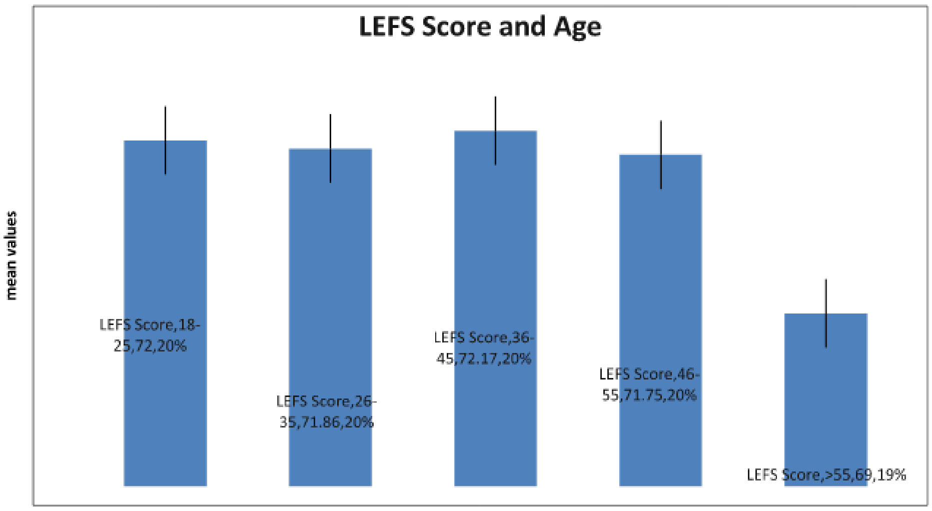


Table: 26 Correlation of LEFS Score with Open/Closed method of reduction

	Closed	Open	P value
LEFS Score			.626
Sample size	37	11	
Mean ± SD	71.78 ± 2.9	72.27 ± 2.9	
Median	72	73	
Min-Max	65-77	66-75	
Inter quartile Range	69.000 - 74.000	70.500 - 74.750	

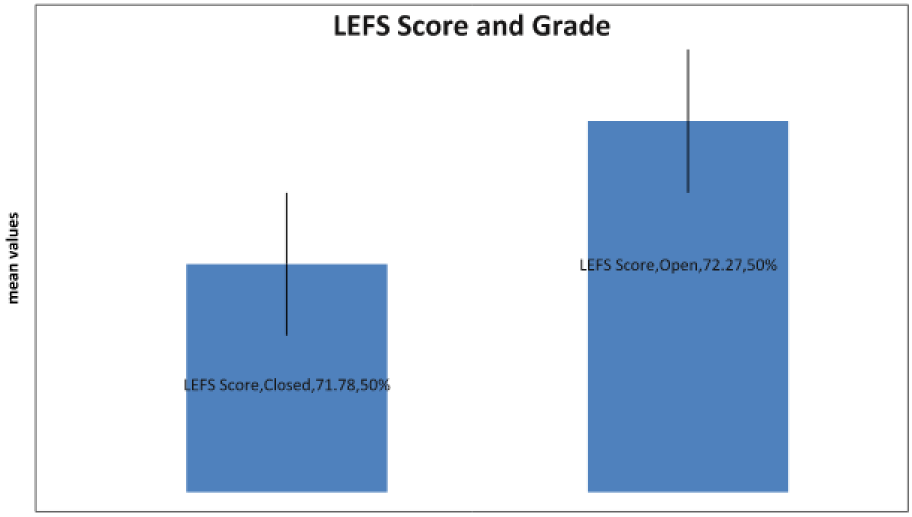


Table: 27 Correlation of LEFS Score With Malroation or No Malrotation

LEFS Score	Malrotation(n=43)	No malrotation(n=5)	P value
Mean ± SD	71.58 ± 2.74	74.6 ± 2.79	.023
Median	72	76	
Min-Max	65-76	70-77	
Inter quartile Range	69 – 74	73 - 76.250	

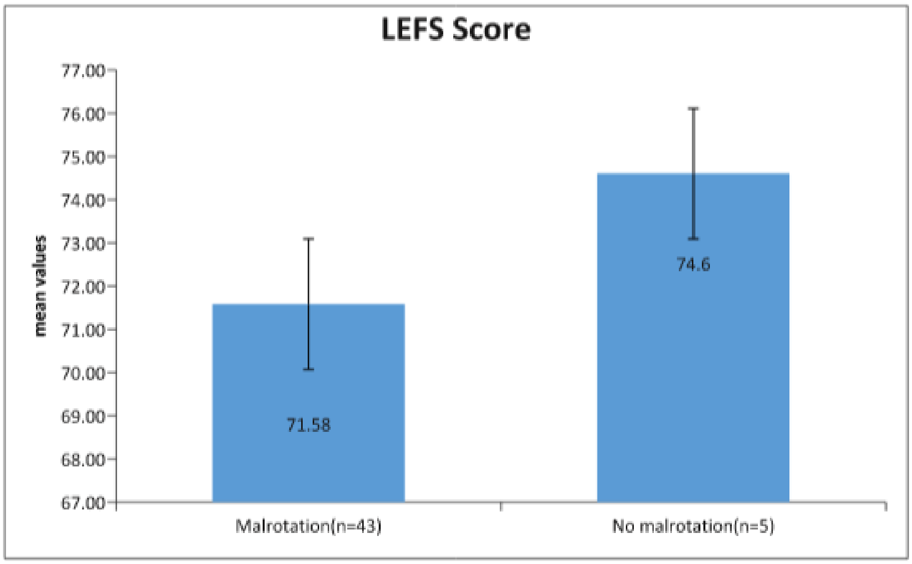


Table 28 Correlation of LEFS Score with External Malroation or Internal Malrotation

LEFS Score	External malrotation	Internal malrotation	P value
Mean ± SD	72.57 ± 3.08	71.1 ± 2.48	0.05
Median	73	71	
Min-Max	65-76	66-75	
Inter quartile Range	71 – 75	69 - 73.250	

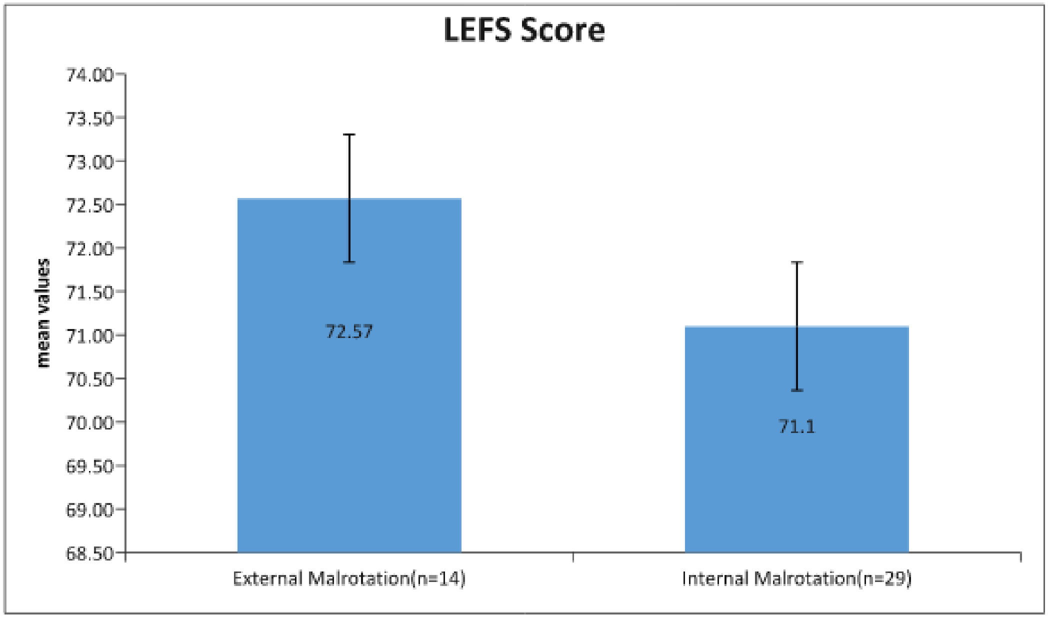
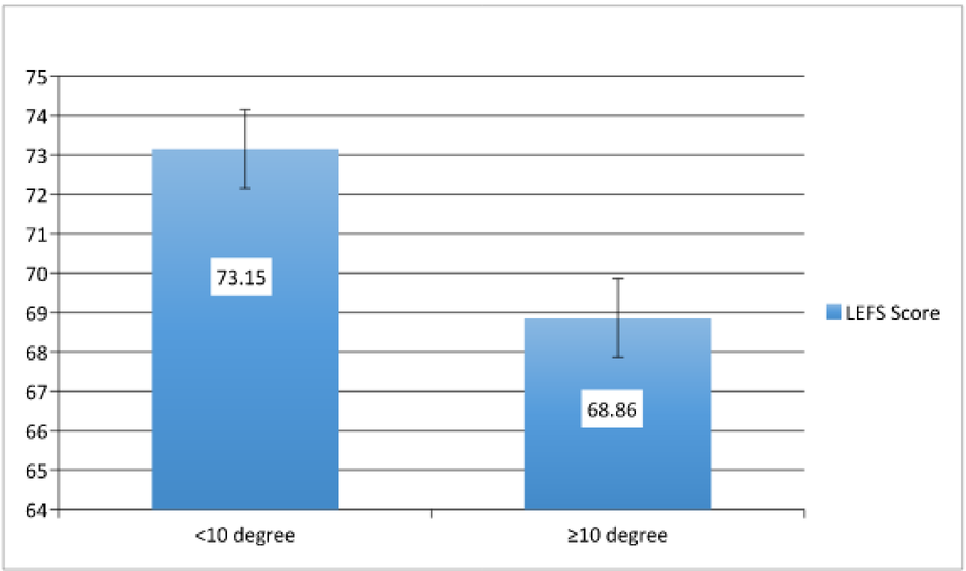


Table: 29 Correlation of LEFS Score with Degree of Malroation (<10 degrees or ≥10 degrees)

LEFS Score	<10 degree	≥10 degree	P value
Mean ± SD	73.15 ± 2.34	68.86 ± 1.41	.001
Median	74	69	
Min-Max	66-77	65-71	
Inter quartile Range	72 – 75	68 – 70	



VI. Conclusion

- On CT evaluation malrotation ≥ 10 degrees is less common than malrotation of <10 degrees.
- Proximal 1/3rd fractures are more prone to malrotation.
- LEFS (functional) scoring is better in patients with <10 than in patients with malrotation ≥10 degrees.
- Roataion should be controlled <10 degrees as functional results are better.
- In proximal 1/3rd fractures alternative methods of fixation such as plating may be preferred.
- Surgeons doing the nailing should be experienced enough or the nailing should be supervised.
- Intra operative method of fracture reduction, supine on table leg partially flexed is superior for rotational control.
- We should look at the tibial spine to control rotation.

- It is better to have external rotational deformity than internal rotation deformity. So if we have to err we can err on the external rotation side.

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