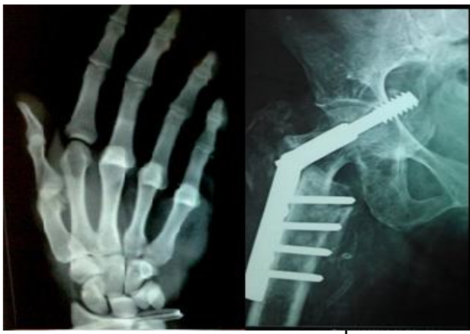

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The use of trans-medullary support screws in proximal and distal metaphyseal fractures of tibia

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Abstract
Purpose: To evaluate the clinical use of trans-medullary support screw (poller screw) as a supplement to stability in metaphyseal fractures of tibia treated with statically locked intramedullary nail.
Material and Method: This was a prospective study of 20 cases of tibial metaphyseal fractures treated with statically locked intra medullary nailing with supplementary trans-medullary support screw between MAY2019 TO MARCH 2020. At PGI SWASTHIYOG PRATISTHAN, MIRAJ. All patients were followed up for atleast 6 months and serial radiographs were taken at 1 month 3 month and 6 months interval. Fractures included were proximal and distal 1/3rd tibia fracture of all age groups.
Result: All the relevant data were analysed.
All the fractures eventually united in a mean period of 11.5 weeks (95% LCL 10.11weeks and 95%UCL 12.88 weeks). Karlstrom-Olerud score was excellent in 13 fractures (65%), good in 6 patients (25%) and fair in 2 patients (10%). The alignment was maintained till union with the mean remaining the same in the coronal plane.
Conclusion: Trans-medullary support screw when supplemented the intramedullary nailing of metaphyseal fractures of tibia,

1. Were effective in achieving the fracture alignment, acting as a reduction tool
2. Improved the stability of the bone – implant construct, by functionally reducing the medullary width
3. Maintained the fracture alignment till union, preventing loss of initial reduction.
4. Maintaing 3 point fixation of the farcture if not maintained by tibia interlock nail.

Keywords: Trans-medullary support screw, metaphyseal tibia fracture

1. Introduction

Treatment of metaphyseal fractures of tibia remains a challenge. The goals of surgical management include correction and maintenance of sagittal and coronal alignment, establishment of length and rotation and early functional range of movements of knee and ankle. Treatment options include medullary implants, half pin, thin wire or hybrid external fixation, plate fixation or combination techniques[1]. Interlocking nailing of tibial fractures are desirable because this technique allows some load sharing, spares extraosseous blood supply, avoids extensive soft tissue dissection and is familiar to most surgeons [1]. Nailing of metaphyseal fractures with short proximal or distal fragment is associated with an increase in malalignment particularly in coronal plane, nonunion and need for secondary procedures to achieve union. The cause has been attributed both to displacing muscular forces and residual instability [2]. As there is a mismatch between the diameters of the nail and the medullary canal, with no nail-cortex contact, the nail may translate laterally along coronally placed locking screws and increased stress is placed on the locking holes to maintain fracture alignment after surgery. Various techniques have been recommended to improve nailing the metaphyseal fractures including blocking screws (poller screw), temporary unicortical plating, different nail designs with different proximal bends (proximal third fractures) and fibular plating (distal third fracture).

Material and Method

This was a prospective study of 20 cases of tibial metaphyseal fractures treated with statically locked intra medullary nailing with supplementary poller screws between May 2019 to March 2020

Inclusion Criteria: Displaced tibial metaphyseal fractures of proximal or distal third in adults treated with intramedullary nailing were included in the study. *The fractures included were acute fractures and delayed union.* Both open and closed fractures were included in the study.

Exclusion Criteria: Tibial diaphyseal fractures were excluded from the study. Metaphyseal fractures treated with statically locked intramedullary nails but with additional procedures like fibular plating were excluded from the study. There were 16 males and 4 female patients with a mean age of 37.75 years [95% lower confidence limit of (LCL) 33.13 years and 95% upper confidence limit of (UCL) 42.36].

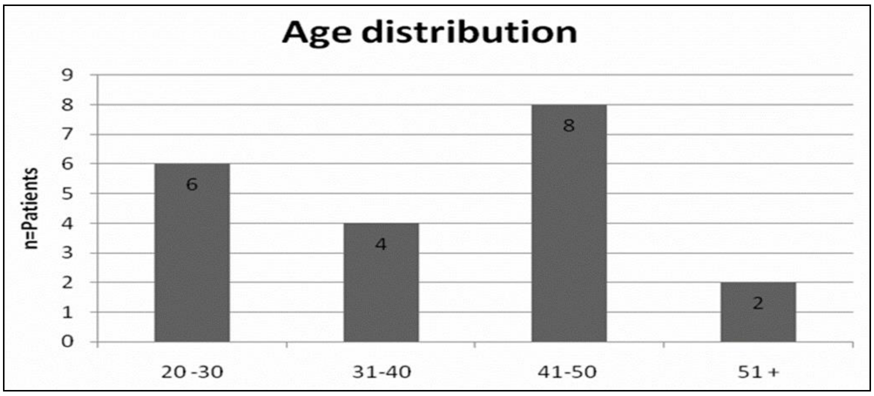

Fig 1: Age Distribution

The injury was on the right side in 12 cases.

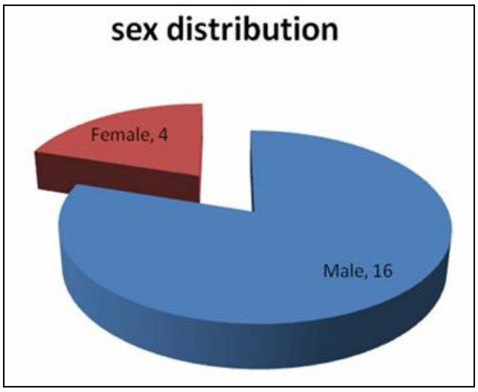

Fig 2: Sex Distribution

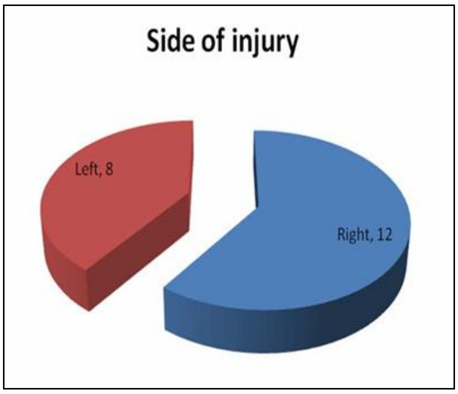

Fig 3: Side of Injury

The mechanism of injury was Road traffic accident in all except three in whom it was fall from height in two and fall of a heavy object over the leg in one

According to AO guidelines there were five type A, eleven type B and four type C fractures.

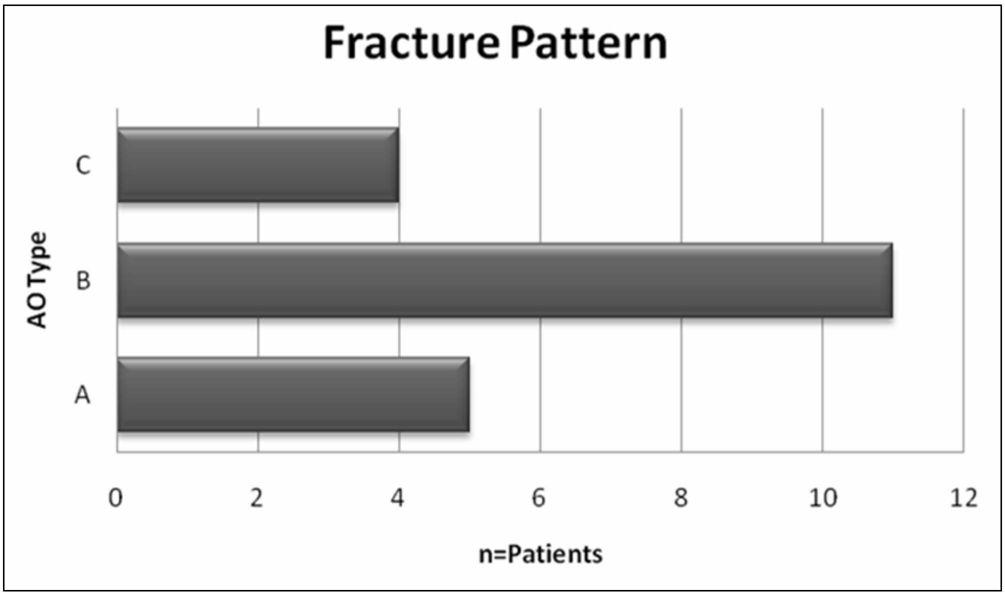

Fig 4: Fracture Pattern

Injury was closed in 15 fractures and Gustillo Anderson grade I in 2 and Grade II in 3 patients.

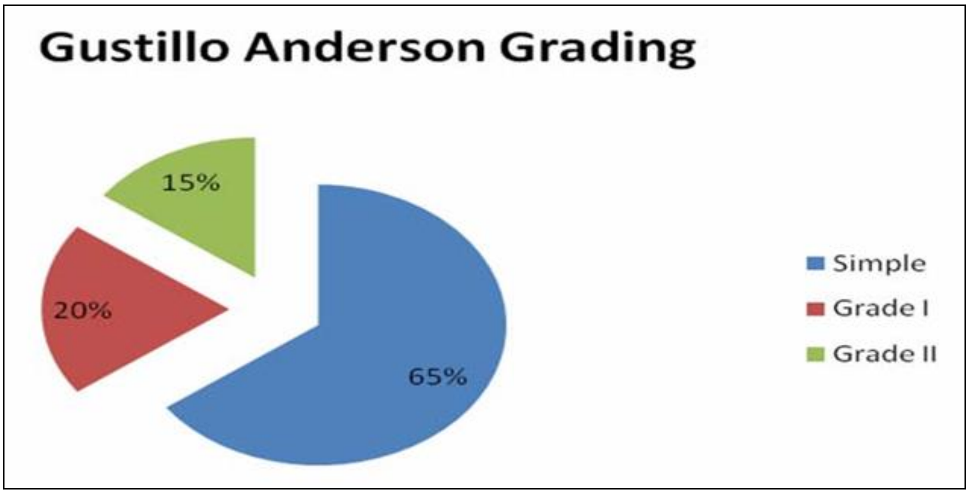

Fig 5: Gustilo Anderson Grading O Fracture

Among the 20 fractures 4 were proximal third and 16 were distal third fractures.

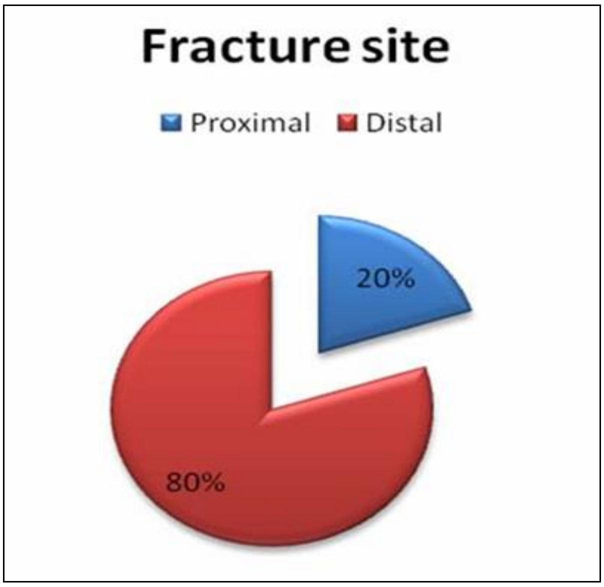

Fig 6: Fracture Site

The mean distance from the articular surface was 5.27 cm (95% LCL 4.20cm and 95% UCL 6.34cm) and the mean length of the fracture was 3.4cm (95% LCL 2.69cm and 95% UCL 4.10cm).

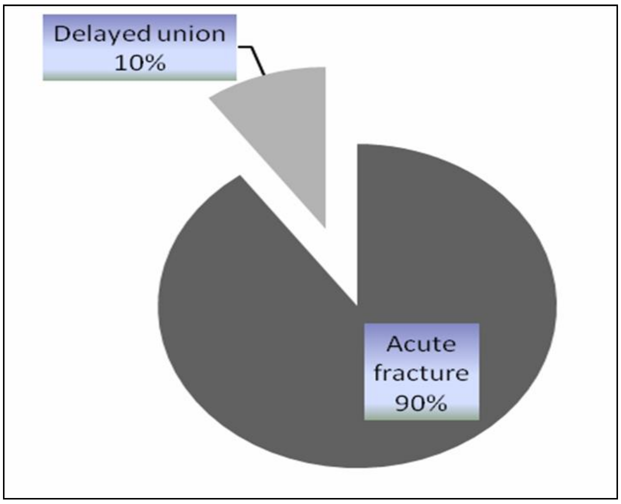

Fig 7: Fracture

The mean delay between the injury and the surgery was 3.75 weeks (95% LCL 1.23weeks and 95% UCL 6.26 weeks). Among the 20 cases two were delayed union of 18 weeks duration.
The mean operating time was 75 minutes.
The mean diameter of the medullary canal at the level of isthmus was
11.9 mm and at the fracture site was 22.9 mm.
The mean length of distal metaphysis was 5 cm and the proximal metaphysis was 7.7 cm.
Poller screws (TSS) were selected for use for one or more of the following reasons

1. To correct alignment after insertion of nail (8 fracture)
2. To maintain alignment or to improve the stability of bone implant complex (20 fractures)
3. To control the nail during insertion (5 fractures)

Table 1: Medullary canal diameter (in mm)

	Mean	S.D	95% LCL	95% UCL
Isthmus	11.9	1.7	11.1	12.7
Fracture site	22.9	6.6	19.8	25.9
Distal metaphysis	50.2	3.5	48.5	51.8
Proximal metaphysis	76.6	6.5	73.5	79.6

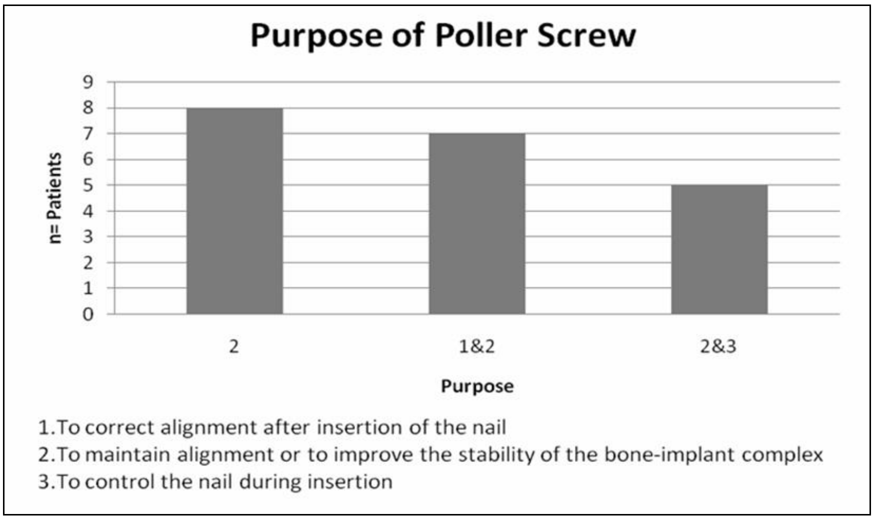

Fig 8: Purpose of Poller Screw

In 8 cases single poller screw (TSS) was used on the concave side of the deformity, close to the fracture site in the short fragment and in rest of cases 2 poller screws were placed, the second screw on the convex side of deformity near the end of the nail in the short fragment.

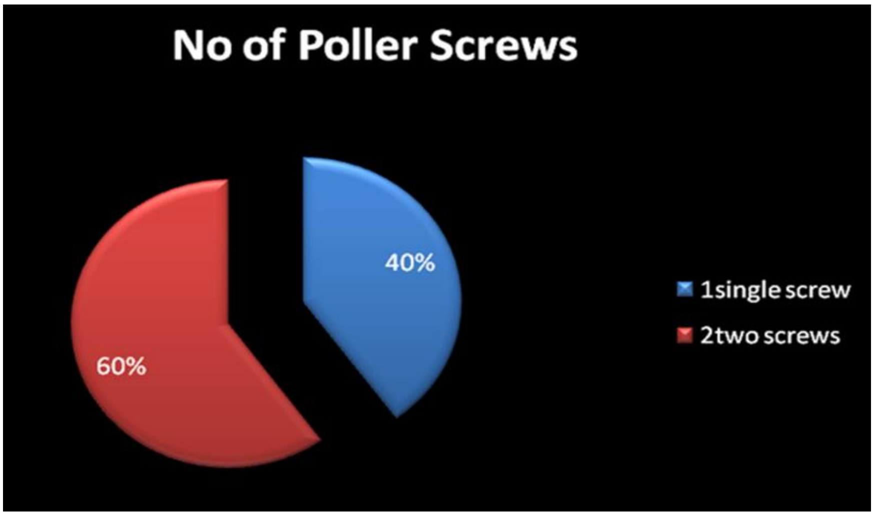

Fig 9: No of Poller Screws

Operative Protocol

Pre-operative planning

X ray of the injured leg in AP & Lateral views, were taken. The fracture tendency for valgus or varus and antecurvatum or recurvatum malalignment was noted. The angle of malalignment was measured.
Fracture was classified according to AO.
Fracture location from the proximal or distal articular surface was measured. The length of fracture was also measured. The diameters of medullary canal at isthmus and at the level of fracture were measured
Appropriate length of the nail was measured in the contralateral leg, from the tibial tuberosity to medial malleolus.
Open fractures were delt with according to AO principles.

Operative Technique: Metaphyseal fractures were stabilized with statically locked intramedullary nails on a standard radio lucent table with manual traction.

All cases were done under spinal anaesthesia. Tourniquet was not used in any case. Through patellar tendon splitting approach, entry point was made 3mm medial to lateral tibial spine. Guide wire was passed under image intensifier control.

Closed reduction was done in all except two fractures. In those fractures, closed reduction was attempted and we had to do open reduction as there was a marked overriding of the fragments and delay of 18 weeks before surgery.

The nails used were reamed cannulated stainless nail, with 2 proximal (mediolateral) and 3 distal (2 mediolateral and 1 anteroposterior) locking options, of diameter 8 or 9 mm. In one case the tibia was too narrow and too short where we have used a nail of 7 mm diameter.

The trans-medullary support screw (poller screw) was used on the concave side of the deformity close to the fracture in the short fragment when single screw was used between the cortex and the nail under image intensification. When 2 poller screws were placed, the second screw was on the convex side of deformity near the end of the nail in the short fragment.

In cases of malalignment and instability the screw holes were drilled with the nail in place while applying manual over correction. 2.5 or 3mm K wire was used to drill the pilot hole for trans-medullary support screw (poller screw) as the drill bit may damage the nail while drilling with the nail in-situ.

For fractures which were stable but malaligned, the nail was temporarily removed, the trans-medullary support screw (poller screws) were placed and the nail reinserted.

Distal and proximal locking was done after achieving the alignment using trans-medullary support screw (poller screws).

The alignment was confirmed in both coronal and sagittal plane with image intensifie

Depending on the amount of correction needed the screws used for blocking were locking screws of different sizes or 4.5mm cortical screws.

Post-operative treatment

Partial weight bearing was started at second postoperative day in all except two cases. In one where we have used 7 size nail and other patient with tibialis anterior tendon was found cut and the patient had both bones fractures in the contra lateral leg, partial weight bearing could not be started. In both the cases cast support was given for 4 weeks.

Follow up

All the fractures were followed through till union of fracture with clinical and radiological examination at intervals of 4 to 6 weeks. The maximum follow up was 16 months..

On follow up axial alignment was assessed and functional analysis was quantified using Karlstorm-Olerud score.

Valgus and antecurvatum were expressed as positive values and varus and recurvatum were expressed as negative values.

Radiographs were analyzed for correction, maintenance of position or loss of reduction.

Shortening and rotational malalignment were not measured.

Fracture was defined as united when patient was able to bear full weight on the injured limb without pain and without support and when radiographs showed bridging callus in at least 3 cortices.

Complications

Complications were divided into those which were related to trans-medullary support screw (poller screw) and those which were not.Complications related to trans-medullary support screw (poller screw) may be mechanical instability leading to nonunion, new fracture lines through the holes for trans-medullary support screw (poller screws), nail failure due to damage by the drill, breakage of poller screw and nerve, tendon or vascular injury due to poller screw insertion[2]. We encountered only new fracture line through the holes for trans-medullary support screw (poller screw) in one case Complications not related to trans-medullary support screw (poller screw)may be compartment syndrome, infection, rotational mal alignment, breakage of locking screw and nerve, tendon or vascular injury before insertion of poller screw [2]. In our series we had only two cases of deep infection and one case of tendon injury.

Results

All the relevant data were analysed.

All the fractures eventually united in a mean period of 11.5 weeks (95% LCL 10.11weeks and 95%UCL 12.88 weeks).

Karlstrom-Olerud score was excellent in 13 fractures (65%), good in 6 patients (25%) and fair in 2 patients (10%).

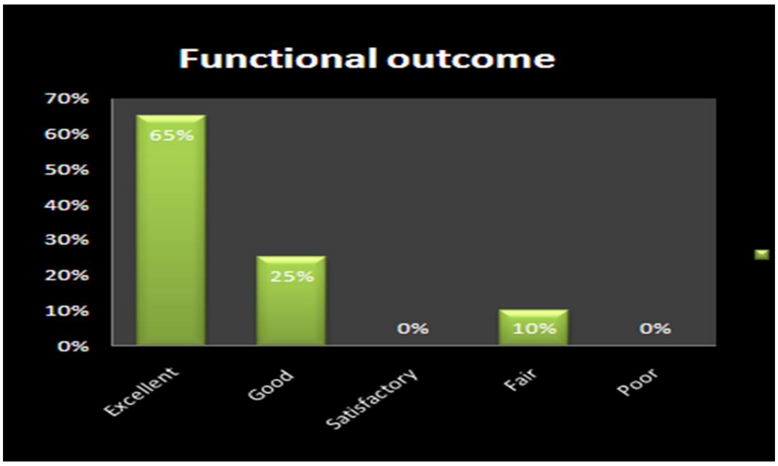

Fig 10: Functional outcome

Radiologically the mean post-operative varus/valgus alignment was $\pm$1.7 degrees (95% LCL 0.5 degrees and 95% UCL 2.9 degrees) when compared to the mean preoperative varus/valgus alignment of $\pm$10.3 degrees (95%LCL 8.2 degrees and 95% UCL 12.4 degrees).

The alignment was maintained till union with the mean remaining the same in the coronal plane.

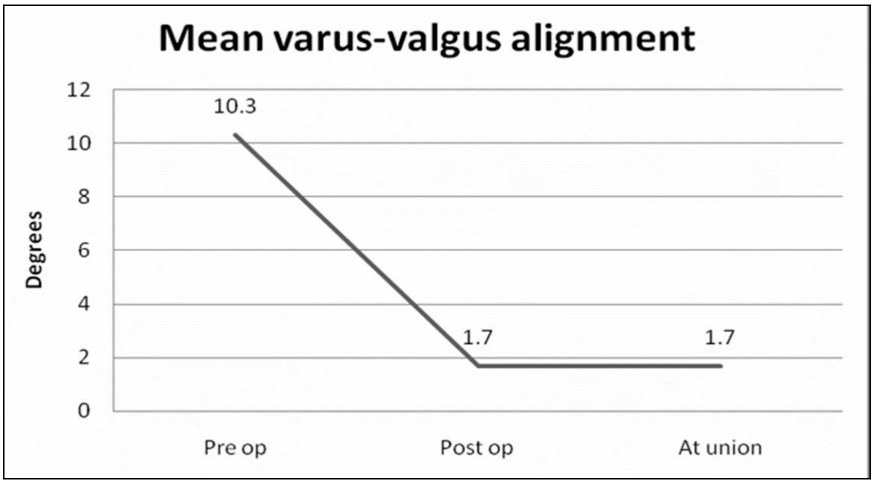

Fig 11: Means varus-valgus alignment

Repeated measures ANOVA test showed the F-test value of 45.29 which is significant as the *p* value is 0.00000 ($p < 0.05$).

The mean post-operative antecurvatum/recurvatum alignment was $\pm$0.2 degrees (95% LCL -0.1 degrees and 95% UCL 0.5 degrees) when compared to the mean preoperative antecurvatum/recurvatum alignment of $\pm$8.0 degrees (95%LCL 4.6 degrees and 95% UCL 11.3 degrees). F test value in repeated measures ANOVA is 22.845 with a *p* value of 0.0000 (<0.05) which is statistically significant.

In only one case of proximal third tibial fracture there was a loss of initial reduction in sagittal plane of 2 degrees, where no trans-medullary support screw (poller screw) was used in the sagittal plane.

The mean antecurvatum/recurvatum alignment at the time of union was $\pm$0.3 degrees, the loss of alignment was not statistically significant.

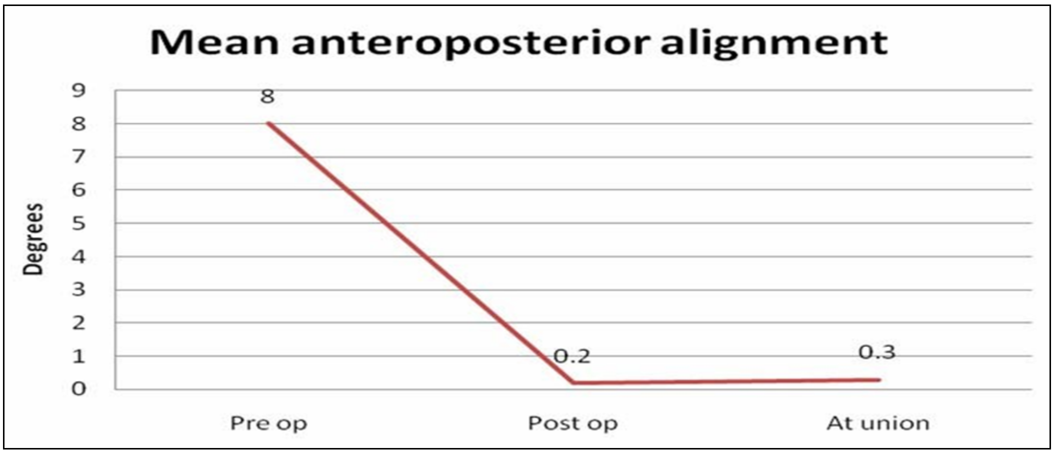

Fig 12: Mean anteroposterior alignment

Table 2: Mean anteroposterior alignment

	N	Mean (in degrees)	Standard deviation
Pre op	20	8.0	7.1
Post op	20	0.2	0.6
At union	20	0.3	0.7

The mean ratio of fracture segment to the nail length (i.e the length of tibia) was 15%.

The poller screw related complication was encountered in one case where we had new fracture lines while introducing the nail after placement of trans-medullary support screw (poller screw). But the alignment was achieved and maintained and the fracture united within 12 weeks.

Complications which were not related to trans-medullary support screw (poller screw) were encountered in three cases. Two patients had deep infection and both of them went in for delayed union of which one required dynamisation to achieve union. In one patient tibialis anterior tendon was found cut at the time of open reduction of the fracture and was repaired. He was given cast support for four weeks.

No complications of nerve injury or compartment syndrome were encountered. There were no incidences of breakage of nail, locking screw or blocking screw.

Discussion and Review Literature

Fracture union was rather difficult to define and measure. Sarmiento *et al* in 1984 specified criteria for the judgment of union [50].

1. The ability of the patient to bear weight without pain.
2. Absence of clinically detectable movements across the fracture site.
3. Visible bridging callus across the fracture on plain radiograph.

In case of operative treatment this criteria doesn't hold good. Panjabi *et al* in 1985 proved that cortical continuity was the best predictor of mechanical strength and the author suggested that measurement of number of cortices bridged was the most reliable measure to assess fracture healing[50].In our series, the union was defined as achieved when the patient was able to bear weight in the injured leg without pain and when the radiograph showed bridging callus in at least three cortices. We cannot over emphasize the potential advantages of intramedullary nailing than any other form of fixation like external fixator or plating in tibial fractures. But the problems in extending the indications to metaphyseal fractures have to be analyzed and resolved. In 1995 Lang GJ *et al* questioned the use of inter locking nailing in proximal third fractures in his review of 32 cases of proximal third fractures. He encountered 84% of malunion i.e. angulations of 5 degrees or more in frontal or sagittal plane and required secondary procedures to achieve union in 41% of cases. Hence he suggested alternate forms of fixation like plate or external fixation [26]

Ean E Nork *et al*, in their review stated that previously reported rates of unacceptable alignment after medullary nailing of proximal third fractures have ranged from 58% to 84% [27].

Ahlers and Von Issendorf analysed 386 fractures of tibia treated by intra medullary nailing of which 32 were proximal and 138 were distal third fractures. In both the groups one quarter to one third had varus- valgus deformities greater than 4 degrees [28].

In another study, Moshieff in 1999 found that 42% of distal third fractures treated with inter locking nailing required secondary procedures to achieve union [28].

There has been discrepancy in the literature regarding the locking bolt orientation and its effect on fracture nail construct stability.

Chen AL compared the intrinsic stability in tibial intramedullary nail constructs in distal third diaphyseal fractures without isthmal support, between two mediolateral distal locking screws and two perpendicular (one mediolateral & one anteroposterior) distal locking screws. He concluded that fixation stability of intramedullary nail is not significantly influenced by distal locking screw orientation in response to sagittal, coronal or rotational forces [30].

I contrary, Smucker *et al* found two parallel locking bolts being a better construct than perpendicular locking bolts in their study [31].

To overcome these issues various techniques have been developed.

In proximal third fractures proximal and lateral entry point was suggested by Buehler KC *et al* and Lembcke O *et al*. Use of semi extended position was proposed as a solution by Tornetta P III [1].Temporary unicortical plating with or without medial femoral distractor was used efficiently to achieve reduction in proximal third fractures by Sean E Nork *et al* and Dunbar RP *et al*. Modifications in nail designs including different proximal bends and more oblique screws have also been put forth as effective solutions [1, 33]. In distal third fractures fibular plating and cutting the distal few millimeters of nail distal to the distal screw hole to allow two cross locking screws in the distal fragment, one cross screw across fracture site as lag screw and use of large reduction forceps and temporary unicortical plating, percutaneous manipulation with Shanz pins, femoral distractor have been the supplementary procedures used to achieve the alignment [31, 32, 34, 35, 36, 37, 38, 39, 40, 41, 42]. The amount of malalignment and shortening considered acceptable is controversial. Tarr *et al* and Puno *et al* demonstrated that distal tibial malalignment may be more poorly tolerated than more proximal malalignment [4]. Trafton's recommendation is generally agreed by many authors. As per Trafton's recommendation the acceptable malalignment is less than 5 degrees of varus-valgus angulation, 10 degrees of anteroposterior angulation, and 10 degrees of rotation and 15mm of shortening[4]. In our study we encountered malalignment in two cases of distal third fracture and in one proximal third fracture (15%).

Effect of mal union

Importance of achieving anatomical reduction in fractures of tibia cannot be over emphasized. Merchant and Dietz in 1989 suggested that for tibial fractures deformity of >5°C was associated with radiographic changes in the ankle[50].Van der Schoot reported a 15 year follow up of 88 patients with fractures of lower leg. 49% had healed with malalignment of at least 5 degrees. More arthritis was found in the knee and ankle adjacent to fracture than in comparable joints of the uninjured leg. Malaligned fractured showed significantly more degenerative changes[43].Puno RM *et al* recorded the long term effects of tibial angular malunion on knee and ankle joints in his 28 tibial fractures with an average follow-up of 8.2 years. His analysis showed greater degrees of ankle malalignment produce poorer clinical results [44].

Kyro A in his series of 64 tibial shaft fractures concluded that malunion of tibial shaft fractures seem to be especially harmful in distal fractures, in fractures with marked previous displacement, in fractures caused by high energy injury and among patients less than 45 years of age[45].We have analysed the mismatch between the diameters of medullary canal at the level of isthmus (i.e. maximum possible nail size) and at the fracture site in all cases.

We found that there was a significant p = 0.0000 ($p < 0.5$) mismatch between them. The diameter of medullary canal at the level of isthmus was 11.9 mm compared to 22.9 mm at the level of fracture site. This mismatch explained the cause of instability in metaphyseal fractures when treated with intramedullary nailing. We have also measured the maximum diameter of the metaphysis both at proximal and distal tibia, there by the length of the metaphyseal segment in our population was arrived. The mean length of proximal metaphysis was 7.7cm and of distal metaphysis was 5.0 cm. The primary aim of the study was to analyze the effectiveness of achieving and maintaining reduction in metaphyseal fractures of tibia treated with intramedullary nailing using supplementary poller screws. As described in various literatures the malalignment in these circumstances were significantly high when done without any supplementary procedures.

Krettek *et al* in 1999 published the mechanical effect of blocking screw in stabilizing tibial fractures with short proximal or distal fragments after insertion of small diameter intra medullary nails. He created bone implant constructs (BIC) in fresh cadaveric tibiae and demonstrated in distal BICs the addition of blocking screws decreased the average deformation of the BICs 57% [$p<0.0001$] and in proximal BICs the addition of blocking screws decreased the average deformation of BICs 25% [$p<0.0001$] [46,47].The effectiveness of blocking screws to help obtain and maintain alignment of fractures of proximal third tibial shaft treated with intra medullary nailing was established by Ricci *et al* in his series [48].

Ai J *et al* explored the effect of blocking screws on the breakage of inter locking intramedullary nails and concluded that blocking screws improve the stability of fracture area

distinctively and hence reduce the breakage of intra medullary nailing [49].
James Kellam in his commentary and perspective on the effect of fibular plate fixation on stability of simulated distal tibial fractures treated with intramedullary nailing by Anand Kumar *et al* concluded that meticulous intramedullary techniques combined with the use of fibular plate fixation or blocking screws will achieve the best results in maintaining the reduction of distal tibial fractures till union [35].
Kenneth A Egol compared the loss of alignment in distal metaphyseal fractures treated with intra medullary nailing alone and in conjunction with fibular plating. They had immediate post-operative malalignment in three cases in those treated with nailing alone, which were eventually corrected by using blocking screws [34].
Oh CW had encountered malalignment of 14% in poller group and 63% of non poller group in his review of 33 fractures of proximal tibia [51].
The use of poller screw as reduction tool was established in our study by the repeated measures ANOVA test and was comparable to the study by C. Krettek.
Poller screws improved the stability of the metaphyseal fractures after nailing and promoted union in our study. Secondary procedure was required in only one case to achieve union (5%). Dynamisation was done 6 weeks after interlocking nailing in a proximal third fracture who developed deep infection. The fracture was originally a grade II compound fracture treated with external fixator which was removed once the wound healed. Nailing was done 6 weeks after removal of fixator.
No cases required bone grafting, bone marrow injection or exchange nailing.
The ratio of short metaphyseal fragment length to the total tibial length was analysed. The total length of the tibia was approximately derived from the length of the nail used.
The mean ratio was found to be 15%.This indicates that even such short metaphyseal fragments had been effectively stabilized till union with intramedullary nailing when supplemented with poller screw.
Trans-medullary support screws (Poller screws) functionally reduce the width of the metaphyseal medulla, usually it is applied in anteroposterior direction as the coronal plane malalignment is more prone to occur than the sagittal plane. Moreover deformities in the sagittal plane is better tolerated, are less common if the fracture is reduced at the time of initial locking. But when the fracture pattern suggests instability in sagittal plane poller screw should be used in the mediolateral direction. The reduction should be ensured in two planes with image intensification after placing the poller screws and before applying the locking screws.
Paige Whittle A and George W Wood II in their analyses of influence of fibular fractures on maintaining alignment in 40 distal tibial fractures treated with locked intramedullary nailing concluded that 60% of unfixed fibular fractures occurring at the same level as the tibial fracture were malaligned.
In our study, fibular fracture was associated in all but one patient. It was at the same level of tibial fracture in 16 cases, distal to tibial fracture in 2 patients of distal metaphyseal fractures (at the level of syndesmosis) and was segmental in 2 cases. Only 17.5% (3/16) of unfixed fibular fractures occurring at the same level as the tibial fractures, were malaligned, which is not significant.

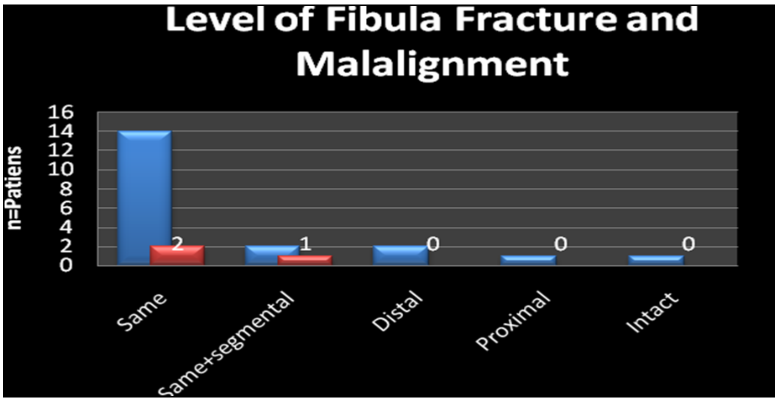

Fig 13: Level of Fibula fracture and malalignment

We found that interlocking nailing when supplemented with poller screw, level of fibula fracture did not influence the stability or the functional outcome.
When compared to other techniques described for preventing metaphyseal malalignment during nailing, poller screws are technically easy, reproducible, do not require any special instrumentation and do not need any special design modifications in the nail. There is no need for excessive soft tissue dissection or additional hardware like unicortical plating or fibular plating. There is no significant increase in radiation exposure for applying poller screws.
In our series the mean ratio of fracture segment to the tibial length was only 15% which denotes that even such short fracture segments can be safely and effectively managed by intramedullary nailing when supplemented with poller screws.
We had excellent to satisfactory outcome in 90% by Karlstrom-Olerud scoring which is comparable to the results of C. Krettek *et al*. with 94% excellent to satisfactory.

Conclusion

We conclude that trans-medullary support screw (Poller screws), when supplemented the intramedullary nailing of metaphyseal fractures of tibia,

- Were effective in achieving the fracture alignment, acting as a reduction tool
- Improved the stability of the bone – implant construct, by functionally reducing the medullary width
- Maintained the fracture alignment till union, preventing loss of initial reduction.

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