Surveillance of biological plating in comminuted fractures of long bones: Our experience at a tertiary care hospital

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Abstract

Osteosynthesis with open reduction technique in comminuted fracture has several disadvantages like increase rate of non-union, non-healing of soft tissue, infection and failure of implant. These problems can be managed by percutaneous minimally invasive plating technique which preserve the vascularity and soft tissue anatomy of fracture fragments.
A total of 40 patients were involved in this study. Distal tibia with or without fibula fracture (12), Diaphyseal tibia (10), Proximal tibia (8), Supra condylar Femur (6) and Subtrochanteric Femur (4) were operated by using the principles of indirect reduction and biological fixation with plates under C-arm guidance. Weight bearing was allowed according to the clinical and radiological union at follow up.
Most patients regained excellent range of motion of adjoining joints. Mean time of radiological union was 20.12 weeks. Two patients had soft tissue infections which healed with wound care and dressing. One patient had non-union which was managed by bone grafting. In this study excellent result was seen in eighteen cases, good in five and fair in other patients.
This study indicates that minimally invasive percutaneous plating is an effective method for treatment of comminuted diaphyseal fracture of long bones. These complex fractures goes onto complete recovery and normal limb function at an early stage with fewer complication.

Keywords: Comminuted fractures, indirect reduction, Bridge plating, Biological fixation, MIPPO

Introduction

The treatment of comminuted fractures of long bones has continued to be a problem in Orthopaedic surgery (Collinge *et al.* 2000) [1]. Major trauma causes endosteal blood flow damages. Periosteal blood flow damage, one of the main sources of blood flow in bones with comminuted fractures, is caused by the usual 'ORIF' method of separation of periosteum and bone, as well as the usage of lag screws and bone clamps (Burgess *et al*. 1987) [2],(Leunig *et al*. 2000) [3].

Different methods of treatment in comminuted fractures are as follow:
1. Standard fixation.
2. Biological fixation.
3. Intramedullary nailing.
4. Pin and cast.
5. External fixators.

Although interlocking intra-medullary nailing is known as the gold standard in the treatment of comminuted fractures, there are limitations in this modality.

For instance:
- i) It is not useful in diaphyseal fractures extending into metaphysis and articular surface.
- ii) Open growth plates in children makes the intramedullary nailing impossible.
- iii) The intramedullary nailing with interlocking usually requires special surgical tools like image intensifier and fracture OT table which are not accessible in all surgical centers (Agus *et al*. 2003) [4].

The duration of surgery for this method is long and unfavourable for patients with time limitations. This method is also high-risk (Tahmasebi *et al*. 2003) [5] and has problems in union, caused by lack of enough compression due to interlocking nails.
In this study, we observed the percentage of fracture union in cases of closed comminuted fractures of long bones of lower limb in adults following biological plating fixation. Also studied the incidence of complications such as infection, refracture, nonunion, mal union or implant failure and observed the use of supplementary bone grafting for fracture healing.

Materials and Methods

The present study was carried out in the Department of orthopaedic surgery from October 2008 to October 2010. A total of 40 patients were subjected to treatment in our present study surgically by minimally invasive percutaneous plate osteosynthesis technique. The age of the patients ranged from 20 to 70 yrs. Out of 40 patients, 29 were males and 11 were females.

Operative procedure
For fractures of tibia

The preoperative planning involves determination of the approximate size of the plate required for fracture stabilisation assuming 3-4 holed purchase is required on the normal bone away from the fracture site. After preanaesthetic checkup the patient was planned for surgery on fracture table in supine position. Surgery was performed under spinal or general anaesthesia. Image intensifier was used throughout the procedure. Traction was given on the affected limb. After taking image both in AP and lateral views the fractures were reduced by close manipulation. Indirect reduction was achieved by using traction via fracture table or by using external fixator or distractor or manually as required. A small incision of approximately 4 to 5cm was given over the appropriate metaphyseal region, proximal or distal to the fracture site under image control. The incision was extended upto the bone. Then a submuscualr tunnel was made with a long periosteal elevator or such instruments, where the plate was to be applied and extended across the fracture to other side. Then the plate was inserted through the incision and held in position by two pointed reduction clamps and fixed temporarily by K-wires, after taking image in both AP and lateral views. With the plate in situ some traction is given manually and the alignment, length and rotation was checked using a standard antero-superior iliac spine, centre of patella- second toe guideline. Then image was taken to check the alignment radiologically and also to confirm the length of the plate, if it was appropriate. The plate was fixed at one end, either proximal or distal according to the fracture site with appropriate screw. Initially a single screw was passed maintaining the bone to plate contact and the alignment. Then remaining screws were given. The plate is fixed proximally or distally with percutaneously introduced screws, through stab incision over the screw holes after localizing holes through image in lateral view and a K- wire. Then thorough cleaning of wound was done with normal saline and wound was closed in standard fashion over suction drain. Post operatively long leg plaster of paris posterior slab was given and the limb was kept elevated. After 48hours the drain was removed and dressing done. Stitches were removed on 10th day (Fig 1, 2).

Fig 1 & 2: Operative procedure for Tibia

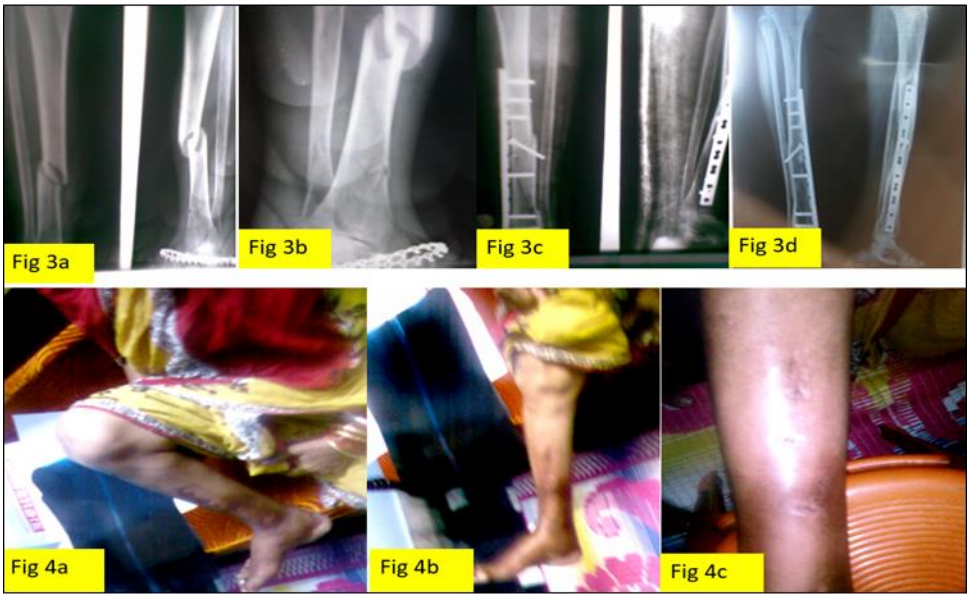

Fig 3 & 4: Procedure for comminuted fracture shaft tibia

Procedure for supracondylar fractures of Femur

Lateral approach is used. The incision is then placed close to the knee joint near the fracture so that it is possible to enter the dynamic condylar screw along with fixation of the intra articular extension of the fracture. The correct screw positioning is checked with radiographs. Once the screw position and length have been accepted, an incision is taken on the skin proximally to the comminuted fracture, so that an intact bridge of skin is maintained between the two incisions. The pre-operatively determined plate is selected and is reversed, so that the barrel faces out and then slipped under the vastus lateralis muscles close to the bone as possible. The passage of the plate close to bone along with the appropriateness of the length and varus or valgus angulation are then checked on radiographs. If the position of the plate is acceptable, the plate is then turned so as to seat the barrel into the screw and the plate is then fixed to the bone. Posterior sag of the proximal fragment is corrected with traction before affixing the plate. The two incisions are closed separately over a suction drainage.

Procedure for subtrochanteric fractures of Femur

Fractures were reduced with traction through a skeletal pin. A 5cm incision was made laterally at the tip of greater trochanter and the deep fascia was incised. A guide pin was inserted into the proximal fragment subtending 85º to the distal femur, with the tip engaging the subchondral bone of the lower quadrant of the femoral head. In the lateral view the guide pin was either centrally or slightly posteriorly positioned in relation to both the femoral neck and head. Anterior or posterior placement was not acceptable. A condylar lag screw was then inserted after reaming over the guide pin with a triple reamer. A barrel plate was inserted with 3 to 4 screw holes distal to the fracture site. A distal incision was made. A track for plate advancement was made extraperiosteally beneath the muscle with a blunt periosteal elevator. The plate was introduced through the proximal incision, keeping the barrel towards the surgeon. The plate was rotated 180º to face the bone and guided over the condylar screw. Proper placement of the plate, frontal and rotational alignments, and leg length were checked. The plate was placed on the distal fragment and fixed with 3 to 4 screws. The compression screw was tightened over the condylar lag screw. Separate drains were used for each wound (Fig 7 & 8). Rotational alignment is checked by the "cable technique"-a cautery wire is used to check that the centre of the head of femur, knee and ankle lie in the same line. Length is checked by confirming the length obtained after traction with that of the opposite limb. It is roughly determined from the tip of the greater trochanter to the lateral joint line.

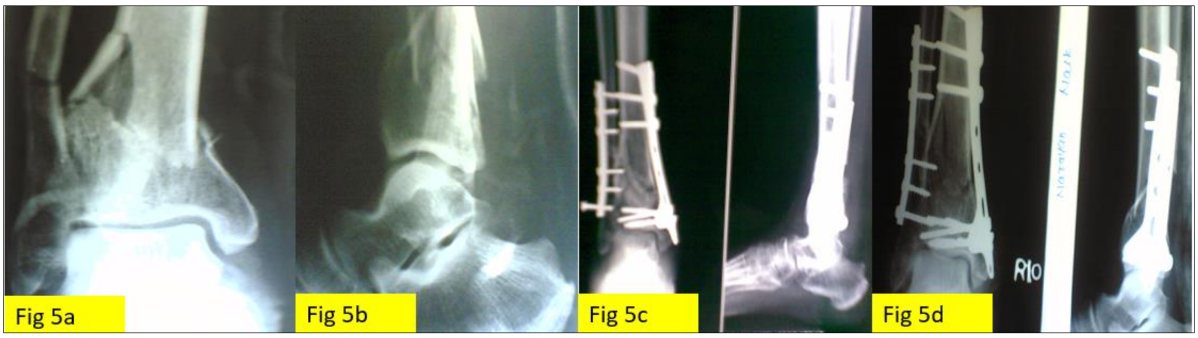

Fig 5 a-d: Comminuted fracture of distal tibia

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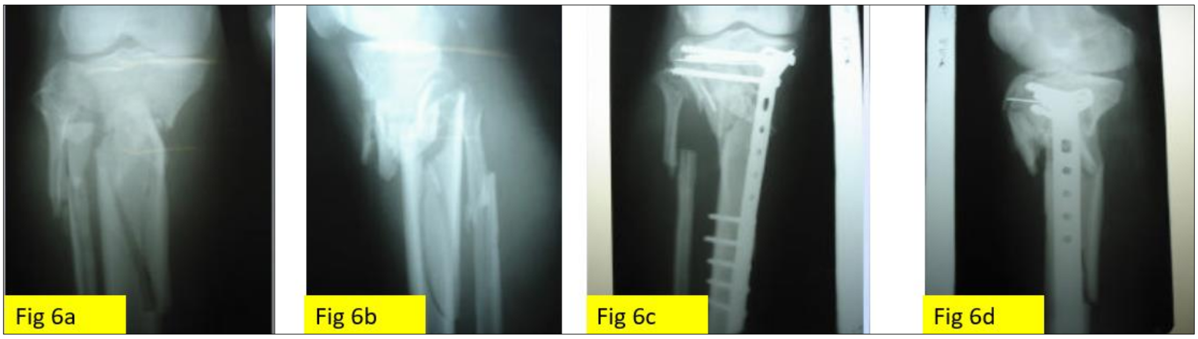

Fig 6a-d: Comminuted fracture of proximal tibia

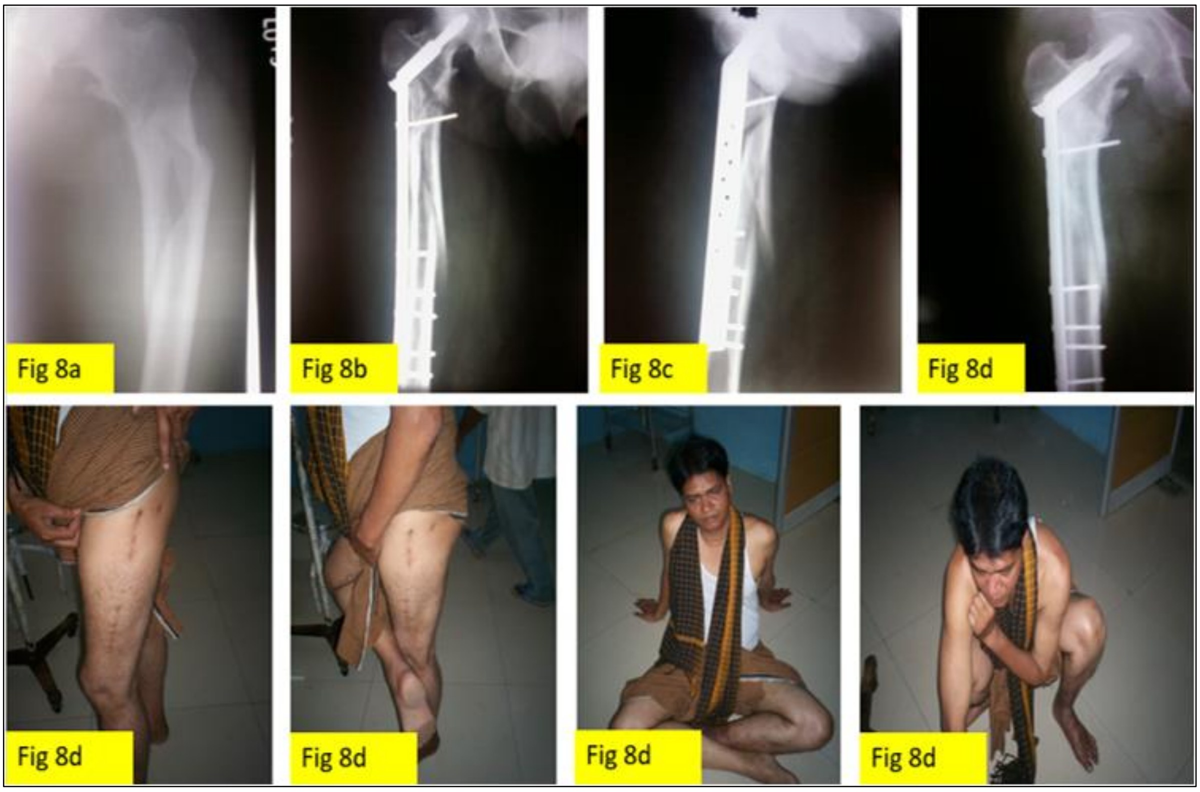

Fig 7-8: Comminuted subtrochanteric fracture femur

Post op follow up

The patients were placed initially on static and dynamic quadriceps exercises and continues passive motion as the patient could tolerate. The knee and ankle movement were started once the pain subsided. Patients were followed up on outdoor basis. Patients were kept on non-weight bearing mobilization till around six weeks when partial weight bearing was allowed and full weight bearing allowed only after good clinical and radiological evidence of progression of fracture healing by third or fourth month.

In the present study 40 patients with lower limb long bone fractures were treated. All of them were managed surgically by minimally invasive percuatneous plate osteosynthesis technique. There were 29(72.5%) males and 11(27.5%) females in this series who were followed up for an average 12 months (range 6 to 24 months). The outcomes as observed in the study is described below.

Results

Table 1: Age incidence

Sl. No.	Age in Years	No. of cases	Percentage
1.	20-30	4	10
2.	31-40	12	30
3.	41-50	18	45
4.	51-60	4	10
5.	61-70	2	5
Total		40	100

Table 2: Sex distribution

Sl. No.	Sex	No. of cases	Percentage
1.	Male	29	72.5
2.	Female	11	27.5
Total		40	100

Table 3: Mode of injury

Sl. No.	Cause	No. of cases	Percentage
1.	RTA	30	75
2.	Fall from height	8	20
3.	Assault	2	5
Total		40	100

Table 4: Types of fractures

Sl. No.	Type of fracture	No. of cases	Percentage
1.	Distal tibia with or without fibula fracture	12	30
2.	Diaphyseal tibia	10	25
3.	Proximal tibia	8	20
4.	Supra condylar Femur	6	15
5.	Sub trochanteric Femur	4	10
Total		40	100

Table 5: Time elapsed between injury and operation

Sl. No.	Time of period	No. of cases	Percentage
1.	<3 days	6	15
2.	3-7 days	24	60
3.	7-14 days	10	25
Total		40	100

Table 6: Types of approaches

Sl. No.	Type of approach	No. of cases	Percentage
1.	Anteromedial	24	60
2.	Anterolateral	6	15
3.	Lateral	10	25
Total		40	100

Table 7: Duration of follow up

Sl. No.	Duration of Follow up	No. of cases	Percentage
1.	Upto 6months	3	7.5
2.	>6-12 months	27	67.5
3.	>12 months	10	25
Total		40	100

Table 8: Complications

Sl. No.	Complication	No. of cases	Percentage
1.	Superficial infection	2	5
2.	Deep infection	2	5
3.	Inadequate reduction and fixation	2	5
4.	Varus malunion	1	2.5
5.	Valgus malunion	1	2.5
6.	Delayed union	3	7.5
7.	Non union	2	5
8.	Peroneal nerve Neuropraxia	1	2.5
9.	Shortening	2	5
Total		18	40

Table 9: Time of clinical union

Sl. No.	Time to union	No. of cases	Percentage
1.	6-10weeks	4	10
2.	11-14weeks	24	60
3.	15-18weeks	10	25
Total		40	100

Table 10: Time of radiological union

Sl. No.	Time to union	No. of cases	Percentage
1.	6-10weeks	0	0
2.	11-14weeks	16	40
3.	15-18weeks	22	55
Total		40	100

Table 11: Range of movement

Sl. No.	Range of movement	No. of cases	Percentage
1.	Near normal	16	40
2.	Partial restriction	18	45
3.	Moderate restriction	4	10
4.	Gross restriction	2	5
Total		40	100

Discussion

According to the above described methods of assessment, 16(40%) cases were excellent, 18(45%) were good, 4(10%) were fair and rest 2(5%) cases were poor.

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Table 12

Sl. No.	Functional grade	No. of cases	Percentage
1.	Excellent	16	40
2.	Good	18	45
3.	Fair	4	10
4.	Poor	2	5
Total		40	100

Despite the notion that soft tissues should be preserved during the open reduction of fractures, surgeons traditionally have sought to achieve maximum stability regardless of the impact on the soft tissues. This traditional approach is responsible for many of the problems for which plating was condemned and later abandoned for certain fractures. The conflict between the need for absolute anatomical reduction and the desire for soft tissue preservation is analogous to saying "wash me but do not wet me".

Age incidence

In this series, out of 40 patients (average age 40.5 years), majority 18(45%) were in the age group of 41-50 years.2 (5%) were in the age group of 61-70 years. In M. Javdan, A. Andalib, F. Fattahi (2007) [6] series of 41 patients with 16 tibial and 25 femoral fractures, mean age was 27.5 years. The peak incidence was between the ages of 21 -30 years. In Sakhvadze Sh. (2009) [7] series of 117 patients with 153 fractures of lower limb, mean age was 42.6 years. The peak incidence was between 31-40 years. In R Rohilla, R Singh, NK Magu, RC Siwach, SS Sangwan (2008) [8] series of 43 patients the mean age was 44 years (range 25-65 years). The maximum affection of young and young adults may be due to increased road traffic accidents involving high speed motor vehicles. The affection of older age group may be due to osteoporotic bones sustaining minor trauma like domestic falls.

Sex distribution

In the present series, majority 29 (72.5%) of patients were males and male to female ratio was 2.63:1. The male preponderance in this series might be due to the fact that males are more exposed to various outdoor activities, as compared to females who remain mainly indoors. In M. Javdan, A. Andalib, F. Fattahi (2007) [6] series of 41 patients with 16 tibial and 25 femoral fractures, 36(87%) were males and 5(13%) females. In Sakhvadze Sh. (2009) [7] series of 117 patients with 15 fractures of lower limb, there were 89 (76%) and 28(24%) females. In R Rohilla, R Singh, NK Magu, RC Siwach, SS Sangwan (2008) [8] series of 43 patients there were 29(67%) males and 14(33%) females.

Mode of injury

In our series road traffic accidents were the commonest cause of fractures as high as in 30(75%) patients. Fall from height contributed 8(20%) of total cases and only 2(5%) were due to assault. This was similar to Pradyumna, PPaiRaiturker, AA Salunkhe (2002) [9] series where they found 13(81.2%) cases were due to RTA, but fall contributed to only 1(6.2%) and assault caused 2(12.5%) of cases. The trend was due to increased use of high speed motor vehicles and increased road traffic problems.

Types of fractures

In this series majority of patients had fractures of distal tibia 12(30%), followed by fractures of diaphyseal tibia 10(25%), proximal tibia 8(20%), supracondyalr femur 6(15%), subtrochanteric femur 4(10%). In Pradyumna, P PaiRaiturker, AA Salunkhe (2002) [9] series distal tibia fractures were 3, diaphyseal tibia 11 and proximal tibia fractures were 2. In M. Javdan, A. Andalib, F. Fattahi (2007) [6] series there were 16 tibial and 25 femoral fractures.

Time between injury and surgery

In this series maximum number of cases 24(60%) were operated within the period of 3-7 days, only 6(15%) cases were operated within 3 days and rest 10(25%) were operated within 7-14 days of injury. Majority of cases were dealt within the first week of injury, which is due to the time needed for all routine and special investigations, to decrease soft tissue swelling and to heal up the superficial abrasions or blisters and last not the least the patient's financial factors. In Pradyumna, PPaiRaiturker, AA Salunkhe (2002) [9] series majority of cases were operated within 1-2 weeks of injury 10(62.5%) and 4(25%) operated within 1 week and rest 2(12.5%) were operated within 3 weeks from in jury.

Type of approach

In this series we used anteromedial approach in fractures of tibia in majority of cases 24(60%) and anterolateral approach in rest of the tibia fractures 6(15%). A lateral approach was used for fractures of femur10 (25%). In tibia comminuted fractures associated with fibula fractures, the fibula fracture was fixed first with standard lateral incision with plates in order to prevent length variations and then tibia was fixed in all cases. In Pradyumna, PPaiRaiturker, AA Salunkhe (2002) [9] series majority of cases were operated with anteromedial approach mostly for distal tibia and diaphyseal tibia 13(81%) and rest through anterolateral approach 3(19%). In M. Javdan, A. Andalib, F. Fattahi (2007) [6] series a lateral approach was used for fractures of femur in all cases. In Nirad S Vengsarkar, Ab Goregaonkar (2004) [10] series and R Rohilla, R Singh, NK Magu, RC Siwach, SS Sangwan (2008) [8] series the fractures of femur were treated with a lateral approach.

Complications

Out of 40 patients operated, 2(5%) patients had superficial infection which subsided by taking oral antibiotics, 2(5%) had deep infection. In adequate reduction and fixation found in 2(5%) cases which lead to nonunion, Varus malunion occurred in 1(2.5%) and valgus malunion occurred in 1(2.5%) of patients. Delayed union occurred in 3(7.5%) but subsequently healed with time. Nonunion occurred in 2(5%) patients which needed a second procedure, like open reduction and bone grafting. Peroneal nerve neuropraxia occurred in 1(2.5%) patient and shortening of 2cm occurred in 2 (5%) patients one with subtrochanteric fracture femur and other with supracondylar fracture femur. In M. Javdan, A. Andalib, F. Fattahi (2007) [6] series there were no wound infections, fistula or the need for secondary surgery due to non -union or implant failure. In tibial fractures there was no malunion. Two femur fractures faced shortening of about1cm. One femur fracture had 2 cm shortening which was caused by great bone defect from shooting. There was no shortening in tibial fractures. In Nirad S Vengsarkar, Goregaonkar (2004) [10] series no patient needed bone grafting as a secondary procedure for delayed union. Complications included infection in one patient and was controlled use of appropriate antibiotics. This fracture then went on to union in a period of approximately four months. Shortening of 1 cm was seen in three patients, but these patients could compensate well and went on to have good function. There was only one case that had some element of malrotation (external rotation). In Pradyumna, PPaiRaiturker, AA Salunkhe (2002) [9] there was a single complication in the form of superficial infection secondary to skin necrosis treated with local debridement and antibiotics. There was no case of delayed union, non-union, implant failure or any significant deformity.

Time to clinical union

24(60%) fractures had clinical union between 11-14weeks, only 4(10%) got clinically united at 6-10 weeks and in rest 10(25%) cases clinical union was found between 15-18weeks. Average time to clinical union was 12.9 weeks. The patients who developed wound infection, the fracture took maximum time to get united. In M. Javdan, A. Andalib, F. Fattahi (2007) [6] series all cases union was completed. The mean time of union in femur fractures was 17 ± 2 weeks and in tibial fractures was 19 ± 2 weeks. In Sakhvadze Sh. (2009) [7] series 143 cases (93.5%) out of 153 complete fracture consolidation was achieved, requiring the average 4.4 months for tibial and 4.9 months for femoral fractures, respectively. In Pradyumna, PPaiRaiturker, AA Salunkhe (2002) [9] Average time taken for full weight bearing was 19.6 weeks (Table 8). It was more for cases with bilateral limb injuries. 82% cases achieved full weight bearing by 23 weeks. Average period for hospital stay was 20 days. In Nirad S Vengsarkar, Goregaonkar (2004) [10] series good union was seen at an average period of three to four months post operatively.

Time of radiological union

In maximum 22(55%) cases radiological union seen at 15-18weeks and in 16(40%) cases union found at 11-14weeks. Average time to radiological union was 15.03weeks. In Pradyumna, PPaiRaiturker, AA Salunkhe (2002) [9] all fractures went to union. 62.5% cases showed union between 14 and 18 weeks, while 37.5% showed union between 19 and 23 weeks. Average period of union was 17.63 weeks. In Nirad S Vengsarkar, Goregaonkar (2004) [10] series good union was seen at an average period of three to four months post operatively.

Range of movement

In the present series 16(40%) patients achieved near normal range of movement of nearby joint according to the type of fracture. 18(45%) had partial restriction of joint movements, 4(10%) had moderate restriction of joint movements and rest 2(5%) patients had gross restriction of joint movements. The mean of hip flexion after treatment was 130 degrees. The mean degree of knee flexion in both groups was 125°, and in only 3 patients with femur fracture the ROM of hip was limited in terminal 30°. 4 patients had limitations in knee flexion which was improved with physiotherapy. There was no limitation in the extension of the knee and hip. Flexion and dorsiflexion of the foot was intact except in 3 patients which improved with physiotherapy. M. Javdan, A. Andalib, F. Fattahi (2007) [6] series the mean of hip flexion after treatment was 130 degrees. The mean degree of knee flexion in both groups was 125°, and in only 3 patients with femur fracture the ROM of hip was limited in terminal 30°. Two patients had limitations in knee flexion which was improved with physiotherapy. There was no limitation in the extension of the knee and hip. Flexion and dorsiflexion of the foot was intact.

Conclusion

In our series 16(40%) cases were excellent, 18(45%) were good, 4(10%) were fair and rest 2(5%) cases were poor. We have followed porter's method of assessment. The 2 poor outcomes were resulted from 2 cases of inadequate reduction and fixation which finally lead to nonunion. In Pradyumna, PPaiRaiturker, AA Salunkhe (2002) [9] long-term final results were rated using point system for pain, function, work ability, joint movement, and radiological and gross appearance. 93.75% cases had excellent to good outcome. R Rohilla, R Singh, NK Magu, RC Siwach, SS Sangwan (2008) [8] series functional outcome was excellent (>90) in 12 and good (80-90) in 31 patients. The mean Harris hip score was 88 (range, 80-99) and the mean Merle d'Aubigne score was 17.

The treatment of complex comminuted fractures has been a problem for the orthopaedic surgeons. These have been treated by conservative methods earlier in the form of plaster casts or traction but unfavourable results with regard to joint mobility and prolonged recumbency were the problems. Conventional plating in which the fragments of the fractured bone were put together, regardless of the soft tissue attachments also led to a lot of complications like nonunion, delayed union, implant failure, etc. To overcome such problems biological plating techniques were introduced for management of such fractures. Intramedullary nailing is also an established method in the treatment of comminuted diaphyseal fractures. Extended indications also include the proximal and distal metaphyseal fragments. Minimally invasive percutaneous plate osteosyntheses is on the contrary the treatment of choice in periarticular multifragmentary fractures. No special instruments are required in this technique. It can be used in the transition zone fractures where intramedullary nailing is very demanding.

Minimally invasive plate osteosynthesis does not make bone grafting unnecessary, but reduces the rate considerably compared to conventional plating in comminuted long bone fractures. Stress is also distributed over a longer length of plate which is without screws and therefore fatigue failure of the implant can be expected later, leading to more time available for the biological buttress to develop.

Important features in this mode of treatment are obtaining length, rotational alignment, and angulation correction and placing the plate in the correct plane as close to the bone to permit biological union. The average reported blood loss with this method in literature is 740 ml with the average duration of surgery being two hours. In conclusion we find biological plating a technically easy procedure to master with the use of a conventional implant, with radiography not being mandatory and especially useful in comminuted fractures with intra articular extensions.

Advantages cited for MIPPO are

1. Simpler technique and easy to master, Learning curve is short.
2. No need of additional expensive instruments.
3. Improved rates of fracture union.
4. Decreased infection rate.
5. Decreased need for secondary bone grafting.
6. Ideal technique for managing poly trauma patients.
7. Early mobilization of the limb is possible.
8. Decreased incidence of refracture post implant removal.

With longer follow-up and a larger number of patients, it seems that the minimally invasive percutaneous plate osteosynthesis for management of comminuted fractures of the long bones of lower limb will prove to be a feasible and worthwhile method of stabilization. It has been rightly said by well-known anatomist R Schenk (1997)", If the fracture surgeon does something 'LOGICAL' then 'BIO' will do the rest"

Conflicts of interest

There are no conflicts of interest.

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References

1. Collinge C, Sanders R, Di Pasquale T. Treatment of complex tibialperiarticular fractures using percutaneous techniques. Clin Orthop Relat Res. 2000;375:69-77.
2. Burgess AR, Poka A, Brumback RJ, Flagle CL, Loeb PE, Ebraheim NA. Pedestrian tibial injuries. J Trauma. 1987;27(6):596-601.
3. Leunig M, Hertel R, Siebenrock KA, Ballmer FT, Mast JW, Ganz R. The evolution of indirect reduction techniques for the treatment of fractures. Clin. Orthop. Relat. Res. 2000;375:7-14.
4. Agus H, Kalenderer O, Eryanilmaz G, Omeroglu H. Biological internal fixation of comminuted femur shaft fractures by bridge plating in children. J Pediatr. Orthop. 2003;23(2):184-189.
5. Tahmasebi MT, Alami Harandi B, Navab E. Treatment of comminuted fractures of femur and tibia with close reduction and plate fixation. Iranian journal of orthopedics. 1380;1(1):1-9.
6. Javdan M, Andalib A, Fattahi F. Biological plating of comminuted fractures of Femur and Tibia, JRMS. 2007;12(4):186-189.
7. Sakhvadze SH. Biological osteosynthesis as the treatment mode for multifragmental extra-articular fractures of lower limb long bones, Georgian Med News. 2009 Mar;168:15-20.
8. Rohilla R, Singh R, Magu NK, Siwach RC, Sangwan SS. Mini-incision dynamic condylar screw fixation for comminuted subtrochanteric hip fractures, J Orthop Surg. (Hong Kong). 2008 Aug;16(2):150-5.
9. Pradyumna P, Raiturker Pai, Salunkhe AA. Minimally invasive plate osteosynthesis (MIPO) in the treatment of multifragmentary fractures of Tibia. bhj.org.in/2001_4301_Jan/Original_162 htm
10. Vengsarkar NS, Goregaonkar AB. Biologic plating of comminuted femoral fractures. Bombay Hospital Journal. 2001;43(1):169-174.
11. Rockwood & green's fractures in adults (6th edition).
12. Campbells operative orthopaedics (10th edition).
13. Journal of research in medical sciences, 2007 Jul & Aug, 12(4).
14. Archives of ortho & trauma surgery.120,5-6/ap-2000.
15. Bombay hospital journal. 2001;43(1):169-174.
16. Biologic internal fixation of fractures, Archives of orthopedics trauma & surgery. 1990;109:295-303.
17. Clinical aspects of biological plating, Injury. suppl. 1991;22(1):4-5.
18. Open reduction & int. fixation of distal femur fractures using biologic reduction techniques, Journal of orthopedics trauma & surgery. 1996;10:372.
19. Biologic osteosynthesis, Journal of orthopedics trauma. 1997;11(1):57-60.
20. The evolution of modern plate osteosynthesis, Injury. 1997;28(A):A3-A.