DISSERTATION ON

Analysis of radiological and functional outcome of comminuted long bone fractures managed by Biological Plate Osteosynthesis

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CERTIFICATE

This is to certify that this dissertation entitled **"Analysis of radiological and functional outcome of comminuted long bone fractures managed by Biological Plate Osteosynthesis"** submitted by **Dr. SRIVATSA B S** appearing for Part II, M.S. Branch II - Orthopaedics degree examination in April 2011 is a bonafide record of work done by him under my direct guidance and supervision in partial fulfilment of regulations of The Tamil Nadu Dr. M.G.R. Medical University, Chennai.

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CONTENTS

Analysis of radiological and functional outcome of comminuted long bone fractures managed by Biological Plate Osteosynthesis

AIM

To analyze prospectively the radiological and functional outcome of comminuted fractures of long bones managed by biological plate osteosynthesis in our institute from July 2008 to August 2010.

INTRODUCTION

Modern way of living has lead to increased incidence of high velocity accidents. This has resulted in an increasing number of comminuted long bone fractures. These high velocity injuries tend to affect the young and working population and hence associated with increased morbidity and loss of function. Management of these fractures has always been a challenge. The goal of treatment in such situations is not only to heal the fracture, but also to aid the patient to return to pre-injury status as early as possible. Traditionally the fractures were treated by rigid internal fixation after anatomical reduction. However this was associated with increased soft tissue stripping and hence more instances of non unions, delayed unions and other complications like infections – as the swiss surgeon Fehr has said "in no area of surgery so many mistakes have been made as in operative fracture fixation".

The internal fixation of fractures has evolved in recent decades with a change of emphasis from mechanical to biological priorities[35]. The bridge plating concepts embrace the principle of placing biology before mechanics[35]. More flexible fixation should encourage the formation of callus while less precise, indirect reduction will reduce operative trauma. This approach is described as 'biological internal fixation' – to assist physiological process of bone healing wisely & optimally with minimal amount of operative intrevention". It involves the use of internal fixators with minimal implant-to-bone contact, long-span bridging and fewer screws for fixation. Formerly, internal fixation with a plate aimed at absolute stability to avoid micromovement which could result in loosening of the implant and a delay in healing. The new technique of internal fixation, however, seems to tolerate and even require some degree of mobility of the interface of the fracture. The contact between implant and bone is kept stable using screws which function like locked threaded bolts.

The surgical treatment of fractures underwent an important change around the middle of the last century. Stable internal fixation allowed fractures to unite while maintaining the function of the joints and soft tissues. The positive aspects of internal fixation using compression techniques were restoration of the precise anatomy and early function. Intra-articular fractures could be reduced and stabilized with smooth and congruent joint surfaces which improved the prospect of avoiding post-traumatic arthritis. Precise reconstruction and absolute stability of fixation were considered to be essential preconditions for success.[5,15] Conventional stable internal fixation with precise reduction usually requires a fairly extensive surgical approach to the bone. This contributes to increasing the necrosis which has been initially produced by the injury, consequently enhancing the risk of delayed healing, infection and possibly refracture. A demanding degree of skill and expertise is required at operation to minimize the biological complications following extended traumatic and iatrogenic necrosis.[37]

Recent developments aim to produce minimal biological damage with flexible fixation.[4,35] 'Bio-logical' internal fixation avoids the need for precise reduction, especially of the intermediate fragments, and takes advantage of indirect reduction.[7,32] This principle applies equally to locked nailing, bridge plating, and internal fixator-like devices.[35] Indirect reduction aims only to align the fragments. It avoids exposure of the bone thus reducing the surgical trauma. Flexible fixation is advocated to induce formation of callus and is achieved by using wide bridging of the area of the fracture. Pure splinting without compression results in flexible fixation. The avoidance of biological damage produced by overly precise reduction, the application of too many implants and too extensive implant-to-bone contact should reduce the risk of biological complications and improve healing.

The aim is to produce the best biological conditions for healing rather than absolute stability of fixation and this approach has been shown to give early solid union.[35] Biological internal fixation does not compromise the restoration of early and complete function of the bone, limb and patients, but recognition of the optimum requirements for bone healing now takes precedence, with mechanical stabilization being less rigid while still allowing painless function and reliable healing. The aim is to reduce the complications[3] such as sequestration and infection which may be produced by bone necrosis, with less emphasis on avoidance of delayed or nonunion, which is more easily managed. Knowledge of the scientific background to this more flexible biological approach will allow selection of the proper balance between mechanical and biological priorities according to the individual situation.

HISTORICAL REVIEW

Year	surgeon	Technique
1943	Harold B Boyd	Unusual nonunions treated with single and dual onlay grafts. Dual grafts had better results
1956	Nicoll	Bridging the nonunion with plate and packing it with bone chips
1959	Shelton and Sage	At the Campbell clinic, a modification of Nicoll graft was devised. Full thickness iliac grafts were used to bridge the gaps and compression was achieved by a compression plate
1981	Brunner and Weber	Wave plating of comminuted long bone fractures
1983	Weber and Blatter	Wave plate – wellen plate- the plate was deliberately bent at the fracture site. Cancellous bone graft could be inserted between the plate and the cortex
1984	Muller and Witzel	The successful line of thought lead to the idea of the bridge plate and wave plate. The basic idea was to leave the fracture zone and its fragments undisturbed by fixing the

		plate to the intact part of the proximal and distal fragments.
1988	Perren	Early temporary bone loss is due to a reaction to necrosis and not to stress protection
1995	Wenda et al	Treated 12 extensive segmental and comminuted fractures of the femur affecting the metaphyseal area and diaphysis with long condylar blade plates. 2 incision technique was used
1996	Ram chadda et al	New name for bridging the comminuted fracture site – the sliding/interlocking plate.

Plate osteosynthesis was first reported more than a century ago. Only when antiseptic theatre conditions were established, they came to wide acceptance.

The initial plates were too weak to provide sufficient stabilization. Then the implant design and composition were improved so that the strength of the implants were increased. When AO/ASIF first introduced the concept of internal fixation of fractures, the emphasis was on anatomical reduction and rigid fixation. These techniques showed good union rates in simple fractures. However they seemed to neglect the biological aspects and reaction of cortical bone adjacent to the plate. The porosis was attributed to the stress protection was found to be the result of accelerated remodeling of the necrotic cortical bone.

This resulted in the production of plates designed to decrease their contact with bone causing less interference to the vascularization of the adjacent cortical bone and therefore less necrosis. Thus poor results of anatomical reduction and rigid fixation in complex fractures lead to the development of biological fixation, where in anatomical reduction is not the aim.

BIOMECHANICS OF HEALING IN COMMINUTED FRACTURES

Fracture healing is a biological process, which results in healing of bone injury as in other living tissues. Fracture of the cancellous bone heals by creeping substitution. Fracture of the cortical bone heals by two mechanisms. The first one is the primary bone healing. Here there will be no evidence of callus formation, when there is a direct contact between the cortical bone ends, lamellar bone forms directly across the fracture site, parallel to the long axis of the bone, by direct extension of osteons. This type of healing is known as contact healing. In small gaps of 150 to 200 microns which are practically invisible, the cells form lamellar bone at right angles to the axis of the bone. This is followed by haversian remodeling. This type of healing is known as gap healing.

In comminuted fractures, where there are multiple fragments and large gaps, union takes place by the formation of abundant callus. This type of healing is known as secondary bone healing.

Fundamental understanding of biological and mechanical aspects of fracture repair is important in selection of fracture management techniques. Two physical factors important in understanding of mechanics of fracture healing are stress and strain.[38]

Stress:

Force (N) acting upon a material results in a state of internal stress. The unit of stress is force area i.e, N/m^2. This force deforms a material on which it acts. This is a convenient way to express how the force affects a material locally. For example, comparing two bones, one with half the cross-sectional area of the other, if the smaller bone is subjected to half the force of larger bone, the stress experienced by each bone would be the same (figure 1).

Strain is simply the change in height or length that a bone undergoes during loading divided by its original height or length. Under the same force, a bone twice as long will have twice the length change, but dividing the length change by the original length of the bone shows that the strain is the same in both cases. (If both bones are composed of the same materials, they should both have approximately the same strain under a given stress.)

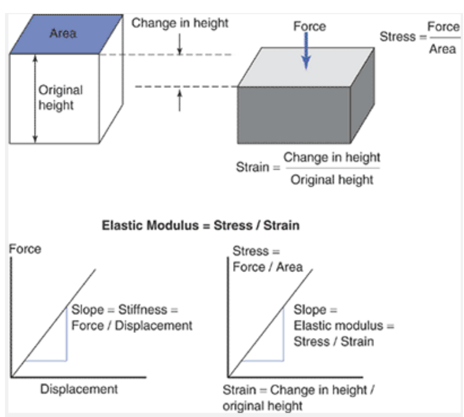


Fig 1: The stress is the force acting on a surface divided by the area over which it acts. Strain is the change in height or length of the object under load divided by its original height or length. Stiffness is as the slope of a force versus displacement Elastic modulus is the corresponding slope, but of a stress versus strain graph. Rockwood and green –ed 6

Thus stress and strain determines the stability (or) instability which ultimately determines bone healing. The degree of instability is best expressed as magnitude of strain. There should be a balance in strain, it should be adequate for mechanical induction of tissue differentiation and at the same time it should be below the critical level for that repair tissue. The critical level varies from tissue to tissue – 2% for lamellar and cancellous bone when compared to 100% for granulation tissue. Strain characterizes the condition of deformation of the bone elements taking to consideration the degree of displacement and the gap width.

For very small gaps (eg. 0.1mm), an imperceptible displacement (0.1mm) may result in very high strain (i.e >100%). It may reach the critical level of strain tolerance of the cell. So a fracture with single narrow gap is very intolerant for even minute amounts of displacements. Strain of individual tissue within the fracture site can be reduced by increasing the gap and /or by sharing the overall displacement by multiple serial gaps and the strain is distributed at the multiple fracture gaps and hence within the critical level. This produces mechanical induction of tissue differentiation by irritation.

To put it in simple words, no gap and almost no strain produces primary bone healing which is seen in a simple fracture stabilized by rigid fixation. Large gaps and low strain promote callus or secondary bone formation which is seen in complex fractures. Hence the reduction need not be precise i.e, anatomical in this situation, because it is more tolerant to displacement as the strain is reduced due to larger gap width and serially located fracture gaps.[7]

Aspects of stability:

The term stability is applied here according to its use in clinical practice, namely to define the degree of load-dependent displacement of the fracture surfaces. When the interfaces of a fracture are compressed, no displacement may be observed, indicating absolute stability of fixation. The surfaces of fractures which have been splinted by implants without application of compression undergo relative displacement. This is proportional to the load applied and inversely proportional to the stiffness of the device used.[41] If rigid internal fixation depends on the avoidance of instability, why then can biological internal fixation take advantage of elastic flexible fixation?

Danis[42] observed that after compression fixation the fracture healed without radiologically visible callus, which indicated that there was a close link between stability and the type of healing. However, the bone regeneration achieved using flexible fixation as described by Ilizarov[43] is outstanding. Indirect healing consists of the sequential steps of tissue differentiation, resorption of the surfaces of the fracture and uniting of the fracture fragments by callus. Finally, the fracture undergoes long-lasting internal remodelling.[44] This is the pattern of healing without stabilization, with stabilization by an external or internal fixator and with flexible internal fixation. Direct healing follows stable fixation and compression; the bone heals without apparent callus[42.] It skips the intermediate steps of tissue differentiation and resorption of the bone surface and progresses directly, although not necessarily more quickly, to the final internal remodelling of the Haversian system.

With absolute stability of fixation the Haversian osteones (figure 2) cross the plane of contact of the fracture without obvious change in shape or direction The same holds true for stably fixed serial microfractures.[35] The question arises as to how a stably fixed fracture proceeds to remodelling. Is local necrosis the stimulus this final phase of repair? Direct healing yields fascinating histological observation. It is rarely a goal in itself but rather a product of maintained absolute stability.

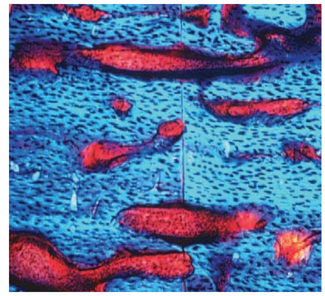


Figure 2: Haversian osteons crossing the fracture site in a case of compression plating

Deleterious effects of instability after rigid internal fixation.

Biomechanical experiments have shown that in cortical bone in sheep a displacement of even a few micrometres at an interface between implant and bone, or bone and bone, induces resorption of the bone surface.[6] In contrast to the generally accepted view that resorption at interfaces to implants is the consequence of the breakdown of bone under excessive load, in these experiments both the displacement and the load were minimal. After conservative treatment the effect of resorption of the fracture surface of the bone is beneficial. The same holds true for flexible fixation. For a given amount of instability resorption increases the distance between the moving surfaces and thus reduces the deformation or 'strain' of repair tissues.[45] The basic working hypothesis of the 'strain' theory[35] is that a tissue cannot be produced under strain conditions which exceed the elongation at rupture of the given tissue element, such as a cell. A minimal amount of strain seems to be a precondition of mechanical induction of callus because stably fixed large defects do not show formation of bone. Compression applied to the fracture produces preloaded continuous contact and thus minimises interfragmentary strain. This enables the osteons to cross the fracture at the compressed surfaces.

Advantages of instability after biological internal fixation.

According to the strain theory an elastic flexible fixation is compatible with the indirect type of healing provided that very small unstable gaps of high strain are avoided. This condition is usually met with indirect reduction by either a bridge plate or a locked nail. The second condition for uneventful healing is that a minimum of biological interference has taken place with avoidance of surgical cleaning of the site of fracture in an attempt to allow overly precise reduction. Based on the observations of Hente et al,[45] the effects of strain may be summarised as follows. The absence of dynamic relative deformation results in lack of mechanical induction of callus formation. Very small amounts of strain induce

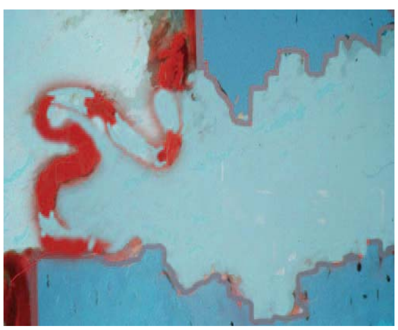


Figure 3: Callus formation in a fracture treated by biological plating

callus formation. Hence biological internal fixation is used for multifragmental fractures.

Means of achieving elastic flexible fixation:

This can only be achieved without interfragmentary compression. A splint is a more or less rigid body which reduces but does not eliminate displacement under load. Attempts have been made to use more flexible implant materials such as fibre reinforced plastics or carbon plates.[31] The effect of the dimensions of the implant on its structural bending stiffness is much greater than are changes in Young's modulus. It is more practical to achieve flexibility by reducing the dimension of a metal implant. A combination of a more deformable metal, such as titanium, and slightly reduced size is usually used. It is advisable to use a highly corrosion-resistant material such as titanium.[46] With this material fretting corrosion can be avoided, but fretting abrasion (galling) may occur. In the presence of minimal corrosion the release of soluble metal into the tissue is negligible but particles are released which may form a visible deposit and these may be transported through the lymphatic system. The major disadvantage of titanium is its limited ductility (plastic deformation before failure), which may be a problem for the expert who limits the amount of tightening of the screw by feeling the 'giving-way' of steel before failure.[47] This can be solved using the principle of locked screws because there is a sharp increase in torque when the screw locks. Elastic flexible fixation may avoid force transmission at the implant-to-bone interface by friction. It is best achieved by solid anchorage of the screws (locked, threaded bolts) within the plate-like connecting bar of the internal fixator.[35]

Biology of healing in comminuted fractures:

Fracture healing is a sequence of inflammation, repair and remodeling. Immediately after fracture, hematoma forms between the fragments and beneath the elevated periosteum. Inflammatory mediators released from the platelets and injured tissue induce neoangiogeneis. As this phase ends the necrotic tissue is removed and fibroblasts appear and produce new matrix,

The repair phase is started by organization of fracture hematoma. Experimental works have show that loss of hematoma slows fracture healing. The hematoma, intact periosteum and soft tissue envelope form a tube which facilitates fracture healing. Often reduction particularly anatomical reduction, may disturb this, thereby retarding the healing process.

The inflammatory mediators recruit pluripotent mesenchymal cells and induce them to differentiate into fibrous, cartilaginous and osseous lineage. The source of the mesenchymal cells is the injured tissue and new blood vessels. The osteoblasts from the endosteal surface also contribute to callus formation. These facts emphasize the protection of the intact periosteum and the new blood vessels. Thus the new bone formation results in the formation results in the formation of the fracture callus. This callus is less stiff and hence deforms under load.

This reparative phase is followed by remodeling phase which converts soft fracture callus and ultimately into lamellar bone of sufficient stiffness to endure physiologic loads. This takes considerably longer time.

Variables affecting fracture healing in comminuted fractures:

Comminuted fractures occur as a result of great violence. Hence they are associated with considerable damage to the soft tissue envelope due to dissipation of the energy, displacement and comminution of long fragments. Secondary to this, there is local disruption of blood supply which results in more necrotic tissues. This impedes new angiogenesis as well as decreases the viability of the mesenchymal cells. Because of severe violence, these fractures may be of compound nature. This leads to even more necrosis and by predisposing to infection, which further increases the risk of non – union.

A unique type of comminuted fracture is segmental fracture. Here the medullary blood supply of the middle fragment is entirely cut off. The viability of this middle segment is entirely dependent on periosteal and soft tissue envelope. If this envelope is damaged either by initial trauma or by surgery, the viability is greatly reduced.

When the fracture gap is less, the amount of reparative tissue needed to fill the gap is less. But when the surrounding soft tissue is intact, lack of apposition may not compromise the healing potential of the fracture.

For the fracture healing to progress, some loading at the repair tissue should be present, because loading a fracture site stimulates bone formation. Controlled loading produces stress and strain, within the critical limits at the fracture site. Strain within the critical limits induces callus formation. For controlled loading to occur, early mobilization is important. Early mobilization results in physiologic loading at the fracture site, increased vascularity, micro motion at the fracture site all leading to fracture healing[38.] Early rehabilitation also leads to improved joint function.

For controlled loading to occur without excessive motion at the fracture site adequate fracture stabilization is important. Excessive loading and motion at the fracture site increase the risks of delayed union and non – union[35]. In many a situation, the comminuted fragments with intact soft tissue attachments serve as vascularised bone graft. Hence primary bone grafting is not needed. It may also violate the hematoma and intact soft tissue envelope at the fracture site.

To summarize, intact hematoma, periosteum and soft tissue envelope, fracture end apposition, controlled loading and adequate stabilization are the factors which promote fracture healing in comminuted fractures.

CLASSIFICATION OF COMMINUTED FRACTURES

Classification systems available for comminuted fractures are the Winquist – Hansen classification and the universal classification system given by the AO group.

Winquist Hansen classification:

Winquist and Hansen classified comminuted fractures into the following categories:

(1) Type I fracture: A comminuted fracture in which a small piece of bone has broken off, not affecting fracture stability

(2) Type II fracture: In which at least 50% contact of the abutting cortices remains to prevent shortening and help control rotation, and in which sufficient proximal and distal cortical contact of the nail is possible to prevent translation and shortening

(3) Type III comminuted fracture: Which has less than 50% cortical contact or in which purchase of the nail would be poor in either the proximal or the distal fragment, allowing rotation, translation, and shortening.

(4) Type IV comminuted fracture: in which the circumferential buttress of bone has been lost and no fixed contact exists

between the major proximal and distal fragments to prevent shortening.

It is primarily used for diaphyseal fractures of the femur and was routinely used to determine whether static locking was necessary. It cannot be used for peri- articular fractures.

AO classification of fractures used in our study:

In applying the OTA fracture classification system, there are five questions that must be answered for each fracture:

- **Which bone?** The major bones in the body are numbered: the humerus is No. 1, the forearm is No. 2, the femur No. 3, the tibia No. 4, and so on. (figure 4)

- **Where in the bone is the fracture?** The answer to this question identifies a specific segment within the bone. The second number of the coding system is applied to the location in the bone. In most long bones, the diaphyseal segment (2) is located between the proximal (1) and distal (3) segments. The dividing lines between the shaft segment and the proximal and distal segments occur in metaphysis of the bone. The tibia is assigned a fourth segment, which is the malleolar segment.

- **Which fracture type?** The fracture type in this system can be A, B, or C, but these three types are defined differently in diaphyseal fractures and fractures at either end of the bone. For diaphyseal fractures, the type A fracture is a simple fracture with two fragments. The type B diaphyseal fracture has some comminution, but there can still be contact between the proximal and distal fragments. The type C diaphyseal fracture is a highly comminuted or segmental fracture with no contact possible between proximal and distal fragments. For proximal and distal segment fractures, type A fractures are considered to be extra-articular, type B fractures are partial articular (there is some continuity between the shaft and some portion of the articular surface), and type C fractures involve complete disruption of the articular surface from the diaphysis.

- **Which group does the fracture belong to?** Grouping further divides the fractures according to more specific descriptive details. Fracture groups are not consistently defined; that is, fracture groups are different for each fracture type.

- **Which subgroup?** This is the most detailed determination in the AO/OTA classification system. As is the case with groups, subgroups differ from bone to bone and depend on key features for any given bone in its classification.

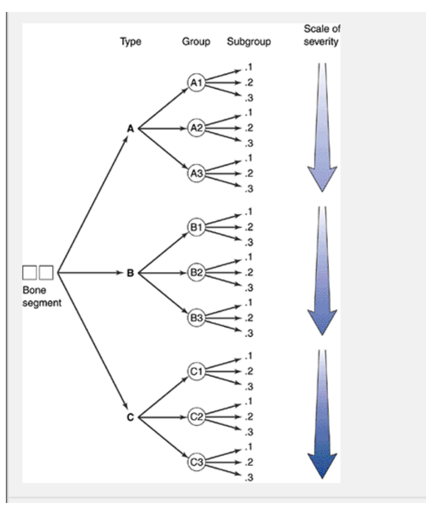


Fig. 4 The AO Classification System

Since it can be used for all the fractures including the peri-articular fractures, and easy to apply and reproducible, we used AO system of classification (figure 5) in our study.

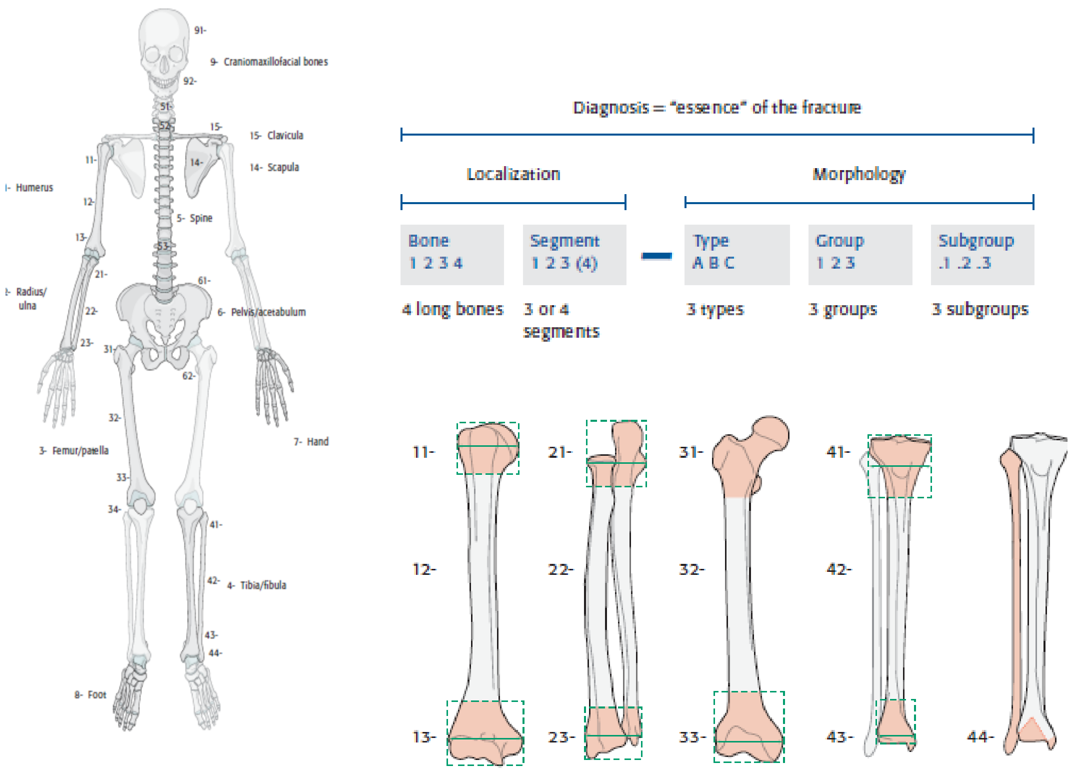


Figure 5: Shows the AO classification of fractures. Taken from AO foundation .org

Principles of biological plating:

The principles of biological plating have been explained in figure 6.

Plate bridges the zone of comminution, there by:

- The fracture hematoma is not disturbed.
- No stripping of periosteum or soft tissue attachments of bone fragments, thus maintaining the viability of the fracture fragments.
- Gives sufficient stability to the fracture site.
- Union depends on the formation of bridging callus and not primary bone union.
- No need for primary bone grafting. Secondary bone grafting can be done in cases of delayed healing.
- Permits micromovement as the stiffness of the plate bone construct is reduced and motion within the fracture gap is achieved during loading

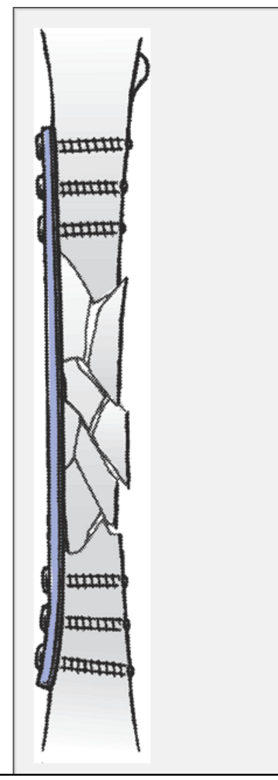


Figure 6: principles of biological plating (taken from Rockwood and green 6th edition)

Advantages:

Biological plating does not disturb the fracture hematoma, intact periosteum and soft tissue attachments of bone fragments. This preserves or maintains the pluripotent mesenchymal cells capable of giving rise to osteoblastic progenitor cells and vascularity of the fracture fragments.

Restoration of limb length and rotational alignment by closed methods – femoral distractor, wagner's device improves the functional outcome. It gives sufficient stability, so that early mobilization can be started. This imparts functional load and strain within the critical limits which in turn promote the callus formation. Early mobilization also contributes to the improved functional outcome.

The union in comminuted fractures depends on the formation of bridging callus. This type of callus formation is particularly advantageous and can be explained biomechanically. The strength or stiffness of any structure depends on the geometric factor and the strength or stiffness of the material within.

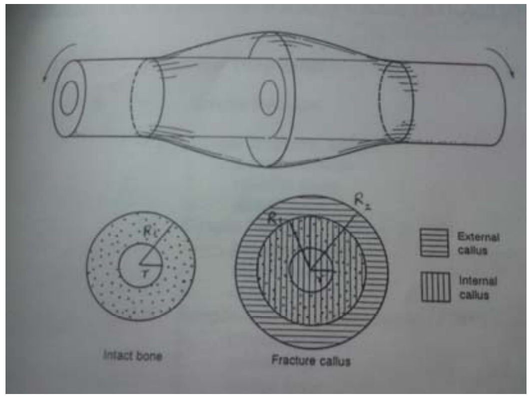


Fig 7: Figure showing the cross section of internal and external callus

Thus the bridging callus has the modulus of three times that of intact bone (figure 7). This means the callus material needs to be only 1/3 rd as strong as intact cortical bone to give the healing bone a normal strength. Thus the higher geometric factor compensates for mechanical weakness of the callus formation. The controlled micromotion produced by early rehabilitation helps in rapid formation of callus. This helps the patient to bear weight earlier when compared to rigid fixation which results in much slower primary bone healing. Moreover rigid fixation has its own perils by violating the biology at the fracture site.

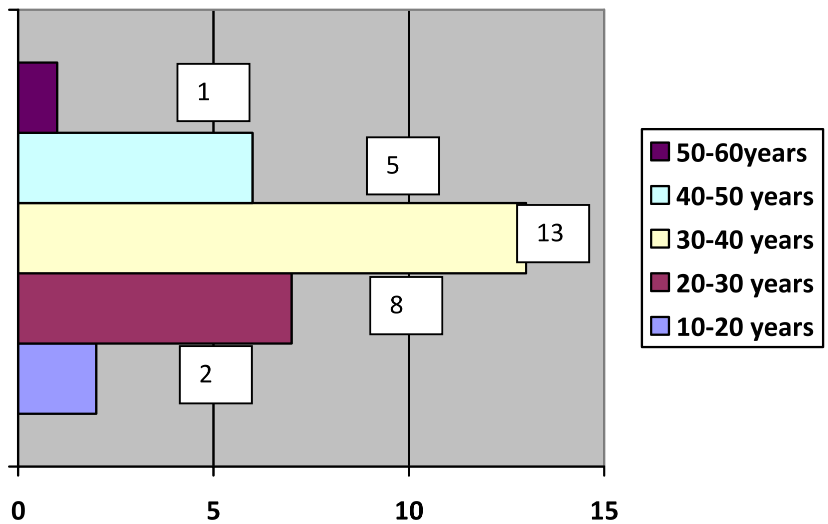
MATERIALS AND METHODS

Patients who sustained comminuted fractures of long bones were treated by the method of Biological plate Osteosynthesis during the period of July 2008 to August 2010 at Institute of Orthopaedics and Traumatology, Madras Medical College and Government General Hospital, Chennai. A total of 32 cases were treated, out of which 2 cases lost to follow up and one died because of an unrelated cause and were excluded from the study. 29 cases were followed up over a mean period of 20 months (range – 16-24 months). The patients were either directly admitted in our hospital or were referred from a primary centre after hemodynamic stabilization.

Out of the 28 cases, 11 presented to us within 6 hours of injury, 6 cases from 6 – 12 hours following injury and 7 cases from 12 – 24 hours, and remaining 5 cases presented after 24 hours. The patients were received in our trauma ward, and after hemodynamic stabilization, x-rays of the injured part were taken and the fracture pattern were analysed. CT – scan were done in cases with intra-articular extensions. They were classified according to the AO classification of fractures as it is easily recordable and reproducible. It accurately describes the extensiveness of the fracture. Fractures were immobilized by splinting or by pin traction as per the convenience.

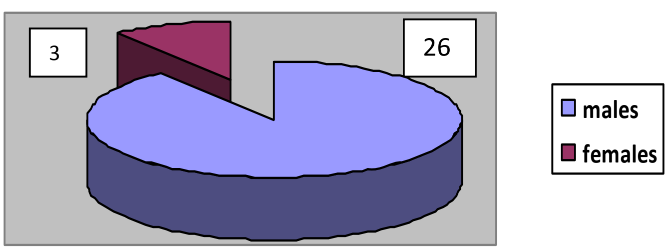
Patient:

Age of the patients averaged 25 years (range 14 to 58 years). 2 were aged between 10-20 years, 8 of them between 20-30 years, 13 were between 30-40 years and 5 were aged between 40-50 years and 1 with age above 50 years (graph 1).



Graph 1: shows the age group of distribution of fractures

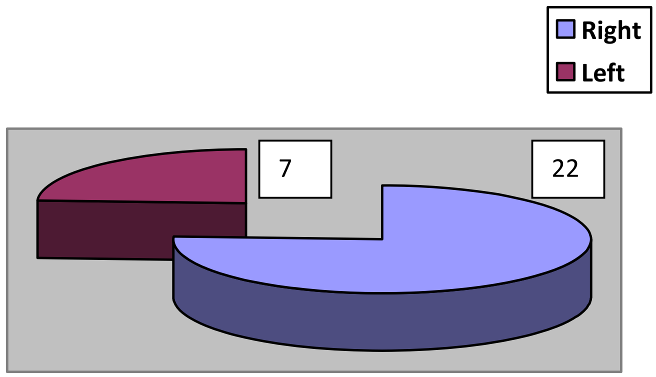
26 of them were males and 3 were females (graph 2).



Graph 2: shows the distribution of fractures in males and females

Fracture characteristics:

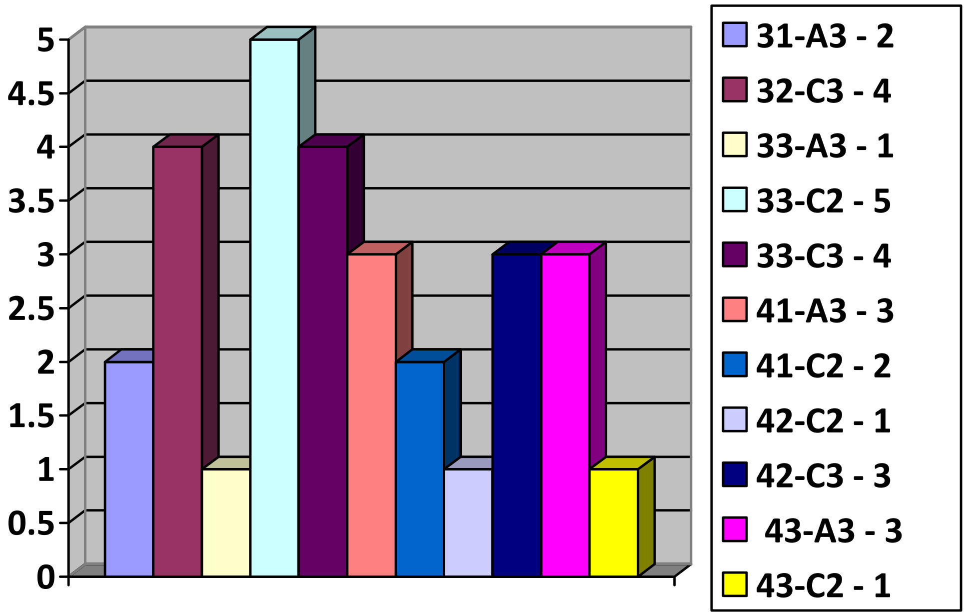
22 fractures involved the right side and 7 of them involved the left (graph 3).



Graph 3: shows the number of fractures involving the left side and right side

All fractures were due to Road traffic accidents except one which was due to fall from height. None of them had injury to other organ systems. However other long bone injuries were present in five patients. Site of fracture included proximal femur in 2 patients, femoral shaft in 4, distal femur in 10, proximal tibia in 5, shaft of tibia in 4 patients, distal tibia in 4 patients. Four of them were compound injuries (12, 13, 14, 17 in master chart) None of them had vascular or nerve injuries. However 1 patient had a tense compartment , which subsided with limb elevation alone.

Fractures were classified as per the AO classification as 31-A3 in 2, 32-C3 in 4, 33-A3 in 1, 33-C2 in 5, 33-C3 in 4, 41-A3 in 3, 41-C2 in 2, 42-C2 in 1, 42-C3 in 3, 43-A3 in 3, 43-C2 in 1 (graph 4).



Graph 4: shows the type of fractures and its frequency

Injuries to the other organ systems were ruled out and the patients were haemodynamically stabilized, sometimes with blood transfusion. Limb was careful examin for the presence of any old scars, condition of the skin and vascularity Other co-morbid conditions were taken into consideration and adequately controlled. A thorough pre – anesthetic check up was done before taking up the patient for surgery.

Duration to surgery:

Every attempt was made to fix the fracture as early as possible. However delay occurred in some cases because of poor skin condition or presence of co – morbid factors. The average duration to surgery was 3.64 days(range – 1-14 days). In cases of grade II and grade III compound injuries, initial wound debridement was done and external fixator was applied until the skin condition was improved. This was co-related with laboratory investigations – ESR and C-reactive protein value and the patient was taken up for definite surgery when these factors normalized. Hence they were operated after 12 days in 2 cases (case 12 and 13 in master chart) and on the 14^{th} day (case 14 in master chart) in the remaining case.

Operative technique:

All cases were done under regional anesthesia on a radiolucent fracture table. Image guidance was used in all cases. Traction was used in Sub trochanteric fractures and in selected cases with more comminution, length was maintained using a femoral distractor (figure 8). A femoral distractor also helps in getting indirect reduction and maintaining the axis of the limb.

Figure 8: femoral distractor applied for a comminuted fracture shaft of femur

A double incision technique (wenda)[39] was used – one proximal and one distal. In fractures of femur both incisions were placed longitudinally on the lateral surface. And in fractures of tibia, a transverse and a longitudinal incision was used. Occasionally a single incision was used with multiple stab incisions for the screws.

An extra –periosteal, submuscular / subcutaneous plane was created using a cobbs elevator (figure 9). Care was taken not to devitalize the fragments and to preserve the soft tissue attachments as far as possible. Fracture hematoma was left undisturbed. Once satisfactory alignment was obtained and length was maintained, the selected plate was slided either from proximal to distal or vice-versa as per the convenience and was positioned under image guidance (figure 10).

Figure 9: A cobbs elevator can be used to create a sub muscular/subcutaneous, extra periosteal tunnel

Figure 10: sliding the plate

Implants used:

Proximal femur	DCS with side plate
Shaft of femur	Broad dynamic compression plate
Distal femur	DCS with side plate / distal femur LCP
Proximal tibia	Buttress plate/Locking compression plate
Tibial shaft	Narrow Dynamic Compression Plate / Locking compression plate
Distal tibia	Medial tibial buttress plate / locking compression plate

The plate was fixed to proximal and distal fragments by bicortical screws. The fracture site was left undisturbed. Care was taken to apply atleast 3 screws in both proximal and distal fragments. Also the length of the plate was selected in such a way that it increases the mechanical stability. In sub-trochanteric fractures, after the lag screw was placed, the plate was slided down with barrel rotated 180 degrees, facing the surgeon. Then it was turned and impacted over the condylar screw. In supra-condylar fractures, if there was an intra-articular extension, articular alignment was first restored and then fixed with cancellous screws. Then the supracondylar component was stabilized with LCP / DCS without opening it.

Post operative protocol:

Prophylactic cefotaxime sodium was used in all cases in the peri-operative period. IV antibiotics were given for 3 days, and in cases of compound fractures, it was continued till suture removal. Analgesics were given for adequate pain relief. Sutures were usually removed on the 12th post operative day.

Postoperatively, the patients were mobilized as soon as tolerated. They were made to sit up on the first postoperative day, and they subsequently began physical therapy for muscle-strengthening and active range-of-motion exercises. A continuous hip passive-range-of-motion apparatus was used postoperatively until the patient was discharged from the hospital.

In general, partial, toe-touch weight walking with use of crutches or a walker was maintained for ten to twelve weeks. However, progression to full weight-bearing was individualized gradually over a period of 14 -18 weeks. Physical therapy was continued until muscle strength and a range of motion were regained.

A standard AP and lateral radiographs were taken in all patients post operatively to check the adequacy of reduction and alignment. After discharge from the hospital, routine clinical and radiological evaluation was scheduled at two weeks, six weeks, three months, six months, and one year and annually thereafter. The patients were examined clinically for integrity of the scar, presence of wound infection if any and range of motion. Even though not all patients returned for all of these scheduled visits sufficient number and duration of follow-ups were present. Data, including all complications, were recorded at each visit, the last of which provided the information used for this study. In addition, attempts were made to contact all patients who had not returned for follow-up.

Outcome analysis:

Analysis of functional and radiological outcome was done by the criteria given by Neer-Grantham and Shelton[32,].

It includes three criteria – function, work and anatomical. Unit values are given for each criteria and scoring is based on the unit values. Scores of all criteria are added and final score is given.

The Neer- Grantham – Shelton Scoring[32]:

Functional:

	Pain(20 units)	**Unit value**
5	No pain	20
4	Intermittent	16
3	With fatigue	12
2	Restricts function	8
1-0	Constant or at the night	4

	Function (20 units)	**Unit value**
5	As before injury	20
4	Mild restriction	16
3	Restricted	12
2	Severe restriction	8
1-0	Cane / brace	4

	Motion (20 units)	Unit value
5	Normal or 135 degrees	20
4	100 degrees	16
3	80 degrees	12
2	60 degrees	8
1	40 degrees	4
0	20 degrees	0

Movements in the ankle were measured from maximum possible dorsiflexion to maximum possible plantar flexion. A score of 5 was given for range of motion more than 40^0, 4 for 30 – 40^0, 3 for 20 – 30^0, 2 for 10-20^0, and 1 for less than 10^0.

Work (10 Units)

	Function (20 units)	**Unit value**
5	As before injury	10
4	Regular , but with handicap	8
3	Altered work	6
2	Light work	4
1-0	No work	2

Anatomical (15 units):

Gross anatomy(15 units):

5	Thickening only	15
4	5^{0} angulation and 0.5cms short	12
3	10^{0} angulation or rotation, 2 cms short	9
2	15^{0} angulation or rotation, 3 cms short	6
1	Union with greater deformity	3
0	Non union or chronic infection	0

Roentgenogram (15 units)

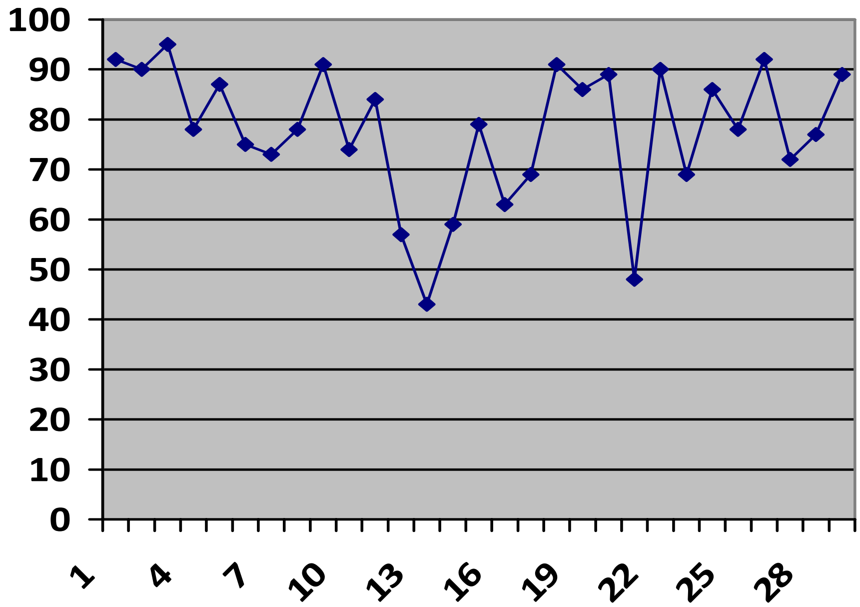
5	Near normal	15
4	5^0 angulation and 0.5cms displacement	12
3	10^0 angulation or rotation, 1 cmsdisplacement	9
2	15^0 angulation or rotation, 2 cms displacement	6
1	Union with greater deformity	3
0	Non union or chronic infection	0

Combining the above scores, overall scoring is given as follows:

Excellent	> 85 units
Good	70 – 84 units
Fair	55 – 69 units
Failure	< 55 units

RESULTS

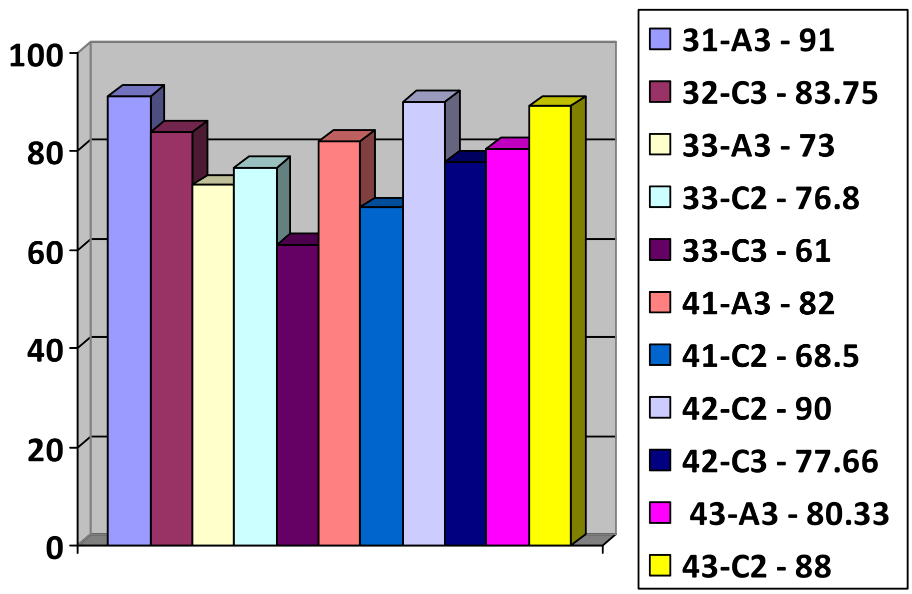
The mean Neer – Grantham – Shelton score was 83 (range – 45 to 95). The clinical outcome was graded as excellent in 12 cases (41.37%), good in 11 (37.9%) cases, fair in 4 (13.7%) cases and failure in 2 (0.068%) cases. The clinical score of the patients is depicted in graph 5.



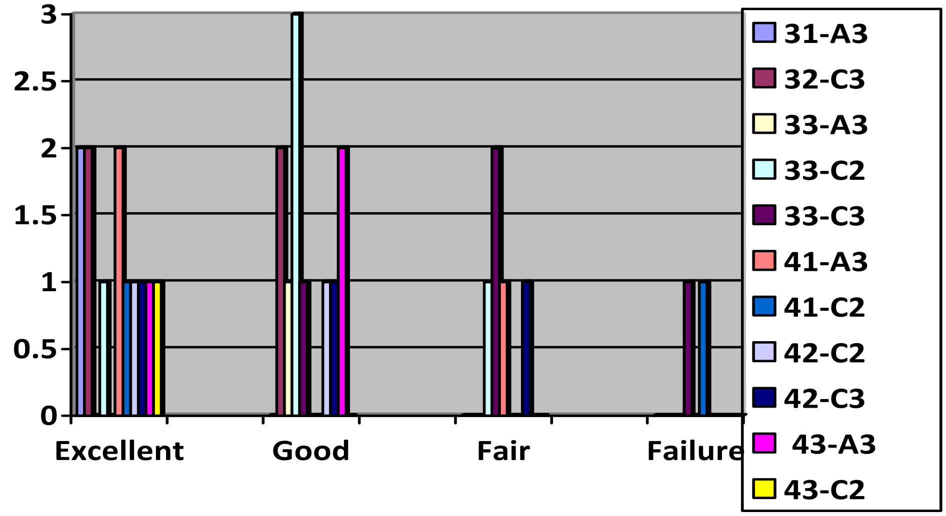
Graph 5: Neer Grantham Shelton Score at the final follow up

When the functional results were analyzed against the type of fracture, it yielded the following results:

The mean Neer – Graham Shelton score was highest for type 31-A3 (proximal femur fractures) and least for 33-C3 (comminuted intra articular with extra articular fractures of the distal femur). It was also seen that pure metaphyseal fractures without intra-articular extension had better outcomes even with presence of comminution (graph 6 and 7).

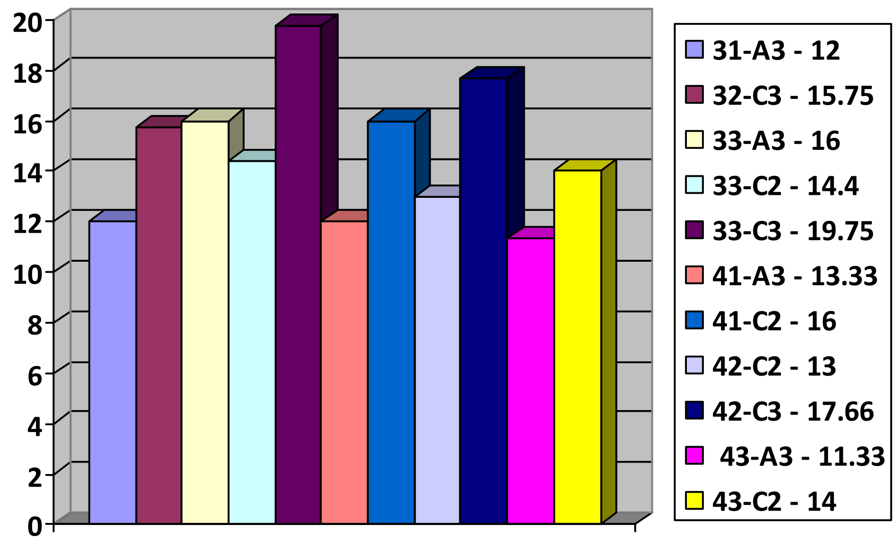


Graph 6: Clinical outcome (Mean Neer – Grantham – Shelton score with respect to the type of fracture).



Graph 7: Distribution of the type of fracture with respect to the final clinical outcome

All cases showed solid radiological union and were able to weight bear by 12-20 weeks (graph 8), except for a case of comminuted tibial shaft fracture (42-C3) (case 23 in master chart), the proximal tibial fracture which also had deep infection and needed ilizarov fixation(case 21 in master chart) and a case of compound distal femur fracture (type 33-C3) (case 14 in master chart) which had delayed union and required bone grafting.



Graph 8: Mean time for radiological union against type of fracture

Except for 3 patients, who had knee stiffness with flexion less than 50 degrees, all other patients had functional range of movements. One patient with type 33-C2 fracture (case 12 in master chart) had implant failure because of premature weight bearing. But since the x-ray showed evidence of callus, she was maintained in a functional cast bracing for 2 months with weight bearing, following which the fracture united. Some degree of shortening was found in 8 patients, but a shortening of 2cms or more was seen only in 3 cases. Axial malalignment was seen in 6 cases (4 with varus of 10 degrees or less and 2 with 20 degrees of valgus). 24 of our patients returned to their previous job and 4 others required a change in job and 1 with compound intra-articular distal femur fracture did not return to any job so far and continues to have aided walking with a stick.

Illustrative cases:

Case illustration :1

- Age/sex/occupation: 57 year/Female/house wife
- Mode of injury: RTA
- Classification: 42-C3
- Procedure: biological plating was done using narrow dynamic plate
- Follow up: 16 months; time to union: 16 weeks
- Range of movements: 0-160 degrees
- Results: Excellent

The parts were painted and draped on a radiolucent table.

A transverse incision was made proximal to the fracture, 5 cms below the knee joint line.

A Cobb's elevator was used to create an extra-periosteal, subcutaneous plane.

NDCP was slided across the fracture under image guidance.

It was fixed to the proximal and distal fragment by 3 screws and distal fragment by 4 screws under image guidance by stab incisions

Immediate post operative Radiograph

Function at 16 months

Case illustration- 2:

- Age / sex: 42 year / Male
- Occupation: shop keeper
- Mode of injury: Sustained RTA
- Classification: 31-A3
- Associated injuries: Nil
- Under image guidance, under traction, DCS plate was applied by technique of biological plating.
- Follow up: 20 months
- Time to union: 12 weeks
- Range of Movement : 0-130 degrees
- Results: Excellent

Case illustration - 2

Pre operative radiographs

Intra op

Immediate post – operative Radiographs

10 weeks post op

18 months post op

Function at 18 months

Illustrative Case 3

Age / sex: 34 years/Male

Mode of injury: RTA

Type of fracture: 33-C2

Occupation: Driver

Procedure: a lateral para-patellar arthrotomy was done and articular alignment was obtained. Then the LCP was slided under image guidance and proximal and distal screws were applied.

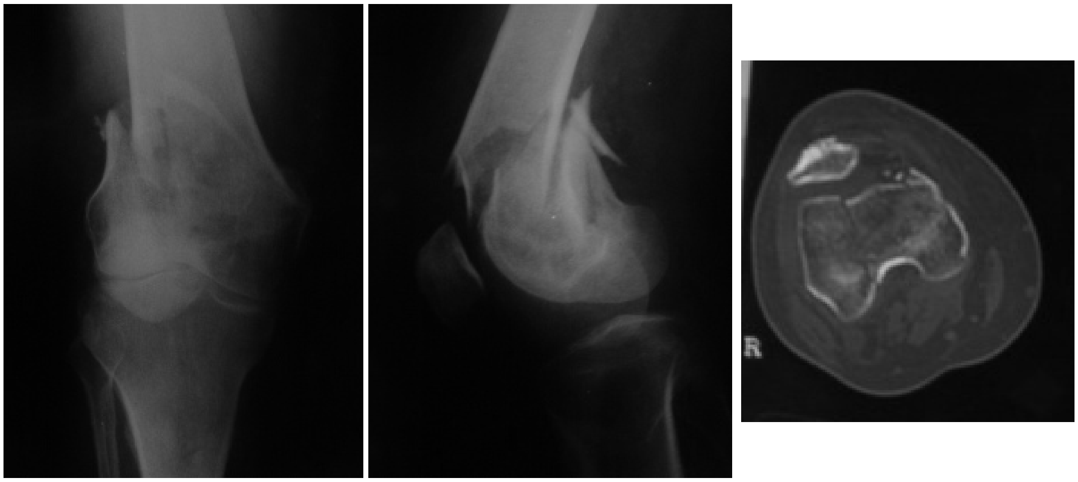
Follow up : 24 months

Time to union: 14 weeks

Range of movement : 0 to 120*

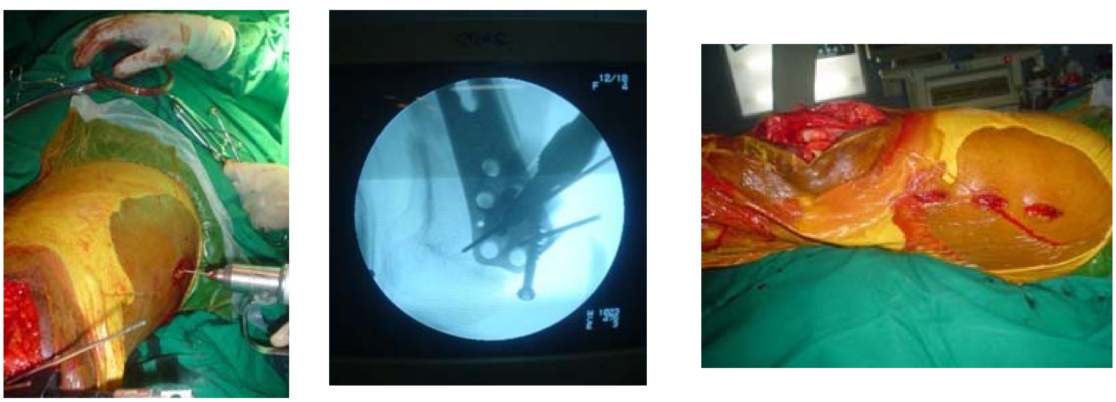
Result : Excellent

Illustrative case 3:



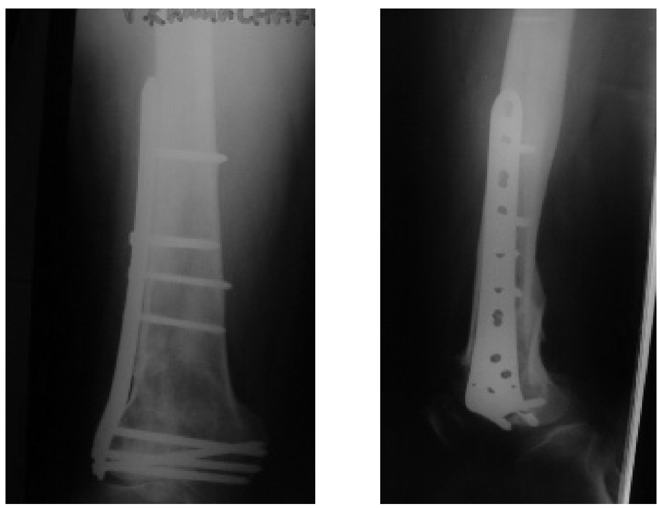
Pre operative radiographs and CT

Plate slided into the sub muscular plane and temporarily fixed with K wire alignment of the plate checked under C arm Proximal and distal screws was applied



Intra operative pictures

Immediate post op



24 months post op

Function at 24 months

Illustrative Case 4:

Age/sex: 40 year/Male

Occupation: clerk

Mode of injury: RTA

Classification: 41-C2

Procedure: After obtaining the articular alignment by a cancellous screw, the buttress plate was slided under c-arm guidance across the fracture site, and was fixed by proximal and distal screws.

Follow up: 14 months

Time to union: 14 weeks

Range of movements : 0-140 degrees

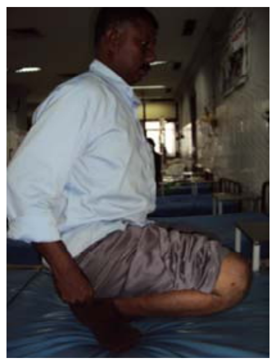
Result: Excellent

Illustrative case :4

Pre op

6 weeks post op

Radiographs at 6 months post operative and after implant exit at 12 months.



Function at 12 months post op

Illustrative Case 5:

Age/sex: 15 years/Male

Occupation: Student

Mode of injury: RTA

Classification: 43-A3

Procedure done: After the fibula was plated, a ‘T’ buttress plate was contoured and was slided from distal to proximal under image guidance. It was secured by using proximal and distal screws.

The skin had abrasions at the time of surgery. The patient developed deep infection and needed implant exit. Only the tibial side implant was removed for the fear of difficulty in skin closure. But the fracture had united well and the patient had a good clinical outcome after the implant was removed.

Follow up: 16 months

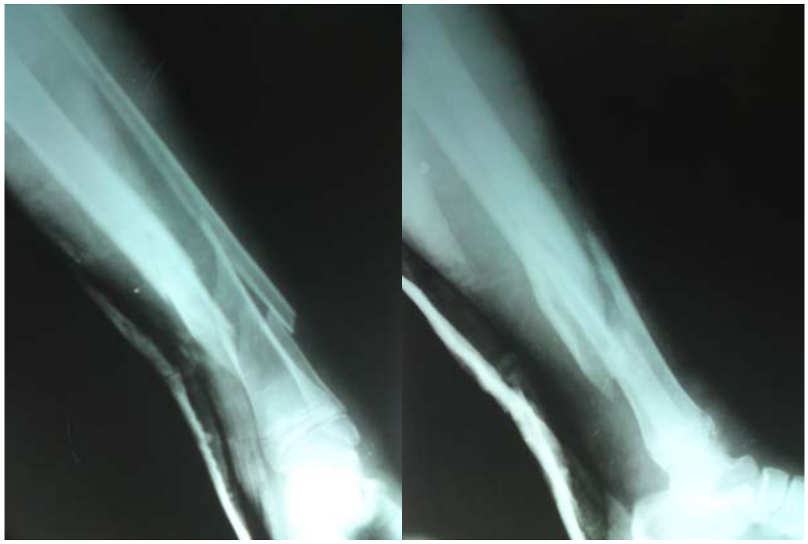
Time to union: 10 weeks

Range of movements: plantar flexion – 0-20degrees

Dorsiflexion – 0-10 degrees

Result: Good

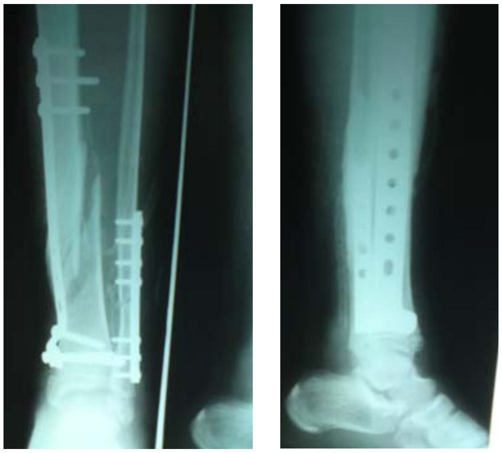
Illustrative case 5:



Pre operative radiograph

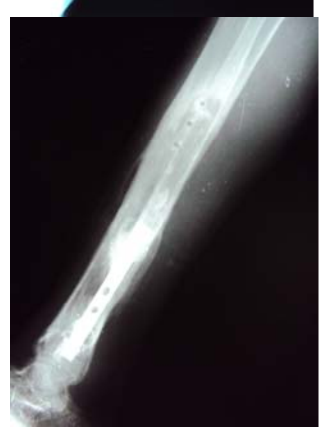
Extra-periosteal tunnel was created using a cobbs elevator

Plate was slided from distal to proximal



Immediate post operative

6 months post operative



The implant was infected and required removal after 6 months. But the fracture was well united and he had a good clinical outcome.

COMPLICATIONS

- **Stiffness:**

This was the most common complication. It was most commonly present in intra-articular fractures around the knee(figure 11). However it improved to functional range with vigorous physiotherapy except in 3 of our patients, in whom stiffness continued to be present even after 1 year of follow up. 2 of these fractures were distal femur fractures with intraarticular extension, 1 being a compound injury, and the remaining one was a proximal tibial fracture, which also had deep infection.

Figure 11: patient with a distal femur fracture developed knee stiffness following surgery

- **Infection:**

2 of our patients had superficial infection, which settled with IV antibiotics, 1 of them being a proximal tibial fracture and the other one being a distal femur fracture. 2 had deep infection, which needed implant exit, out of which 1 was proximal tibial and the other was distal tibial fracture. Patient with distal tibial fracture (figure 12) went on to have union, but the one with proximal tibial fracture needed implant exit before union, which was subsequently managed with ilizarov.

Figure 12: A case of distal tibial fracture treated with Biological plating with wound infection and exposed implant

Figure 13: Non union of type 42-C3 fracture following bone grafting. Also note the presence of valgus deformity.

- **Non union:**

3 patients went in for non union, 1 with infection(proximal tibial fracture), and other 2 were patients with type 42-C3 who was treated with auto-allo grafting (figure 13)and progressed to union by 7 months. Other patient with compound distal femur also had non union and needed bone grafting before progressing to union.

- **Shortening:**

Even though 8 patient had some amount of shortening, only 3 of them had shortening of 2cms or above. All three with such shortening were distal femur fractures with intra articular extensions.

- **Other deformities:**

4 patients had varus deformity, but none of them more than 10 degrees. Two had valgus more than 10 degrees – patient with type 42-C3 who also had non union. This was probably because of premature weight bearing and unilateral plating. Absence of plating on the lateral side did not resist valgus progression. The other patient with valgus deformity was a patient with fracture type 43-A3 and this was because of intra operative difficulty in getting the alignment.

None of our patients had deep vein thrombosis. Only three of the distal femoral fractures required blood transfusion in the peri-operative period.

DISCUSSION

Innovative surgical techniques have been developing over the years with understanding of biomechanics, biology and bio materials. These techniques help us to learn and improvise ourselves which ultimately lead to better functional outcome for patients. Managing severely comminuted fractures is a challenging task. In this study, the aim was to achieve this by using the technique of biological plating.

Fracture fixation using plate osteosynthesis is a demanding procedure and the success is related to the technique that is used. A decade ago more importance was placed on anatomical reduction and rigid fixation to achieve stability. the results, however were not encouraging due to the violation of the soft tissue envelope around the fracture site. This lead to the evolution of newer technique which placed biology ahead of maximal stability[35].

Despite the knowledge that soft tissues should be preserved during open reduction of fractures, surgeons traditionally have sought to achieve maximum stability regardless of the impact it might have on the soft tissues [4]. Baumgaertel et al [5] demonstrated that indirect reduction and bridge plating was superior to direct fragment reduction and anatomical fixation in according to radiologic, biomechanics and micro-angiographic evidences. Faster gap filling and callus formation was shown beginning in the second or third week in indirect reduction, and in the sixth week in direct reduction. In the study of

Agus et al [12] closed comminuted femur shaft fracture were surgically treated by biologic internal fixation using a bridging plate. The mean complete radiographic healing time was 12.4 weeks. After a mean follow-up period of 4 years, all patients were satisfied with the clinical outcome. It was concluded that biologic internal fixation by bridge plating was an effective surgical treatment method for closed comminuted fractures of the proximal and distal thirds of the femur.

Kregor et al[34] had treated 103 patients with distal femur fractures by locking compression plate by biological plating. In his study, out of 103 most of the fractures are Type C fractures .All the patients had union around 12 weeks. Only 7 patients had bone grafting. Average range of movement in his study was109^{o}.71% of the patients had Good results. 6 of them had malalignment and 7 of them had bone grafting. In another study by Schandelmaier et al, [36] 54 patient were treated with locking compression plate for distal fractures .Of 54 fractures, 6 patients had bone grafting and range of Movements are 104^{o}. Most of the distal fractures were type C fractures and 78% of patients had good functional results by Neer – Grantham – Shelton score.

Biggi et al[51] in their study of 58 proximal tibia fractures by this technique obtained good to excellent results in 78% of the patients. Studies by chang-wug et al have shown the beneficial effects of this techniques in proximal tibial fractures. Also quicker post operative recovery of function has been demonstrated in these fractures using the technique of biological plate fixation.

Mohamed Sukeik et[49] al in a retrospective study of 27 patients from two institutions treated for distal tibial fractures using a distal tibial locking plate through the biological plating technique, where in 3 were open injuries, showed union and weight bearing of all the fractures by 10 weeks.

Studies by Rakesh Gupta et al and Shanmugam et al have shown that in distal tibial comminuted fractures, percutaneous plating is associated with earlier clinical and radiological recovery and less number of complications. Helfet et al[50] in their study of distal tibial fractures treated with biological plating had no loss of fixation or evidence of hardware failure. There were isolated cases of delayed union, deformity and superficial cellulitis. All 20 cases showed union.

In our study we have treated 29 comminuted fractures of the lower limb by the method of biological plating. 13 (44.8%) of these fractures yielded excellent results by Neer – Grantham – Shelton score. Outcome was good in 9 (31%) patients and fair in 5(17.2%). Most patients showed radiological union by 14 – 20 weeks and were able to bear weight. Only 2 patients had failure as per the Neer-Grantham- Shelton score. Of the patients with fair and failure group, 6 of them were fractures around the knee with intra articular extensions. other patient was the one with type 42-C3, who went for non union.

In addition to intra-articular extension, the presence of open injuries, associated skeletal injuries, and skin condition at the time of surgery all had an effect on the final outcome. In the compound distal femur fractures managed initially by external fixation and a second stage biological fixation, both patients had fair/poor outcomes, it was also difficult to obtain the articular surface alignment in those fractures.

The operative time and XR exposure tended to be longer for femoral fractures because the femoral condyles were more difficult to reduce, the accuracy of the plate placement at the submuscular tunnel and insertion of proximal diaphyseal cortical screws all needed to be guided by intra-operative XR. While for tibial fractures, the position of the plate at the subcutaneous surface and the screw holes were often directly palpable and so less irradiation was required. Blood loss was significantly more with femoral fractures because either a tourniquet could not be applied or was deliberately omitted to allow insertion of a longer plate.

Care was taken to maintain the alignment and length of the limb during fixation either by the use of traction or femoral distractor. Even then small degrees of mal-alignment did occur in 6 patients (4 patients with varus of 10 degrees or less and 2 patients with valgus of 20 degrees) and this was seen mainly in periarticular fractures, especially around the knee. But none of the deformities were severe enough to limit function or need a secondary corrective procedure. Shortening of 2 cms or more was seen in 3 patients.

Two of our cases had deep infection, out of which the patient with proximal tibial fracture was a diabetic and the one with distal tibial fracture had a poor skin condition at the time of surgery. In the patient with non union of the tibial shaft fracture, the non union was probably because of the ischemia to the compartment during the peri-traumatic period.

Indirect reduction is technically challenging. Early surgery, careful planning, intra-operative fluoroscopic monitoring and accurate contouring of the plate were essential to avoid malalignment and implant impingement. We used the 4.5 mm lateral tibial head buttress plate instead of the cloverleaf, one-third tubular plate, 3.5 mm DCP or 4.5 mm DCP because the implant had a strong straight stem for insertion of cortical screws and a flared metaphyseal portion for insertion of multiple 6.5 mm cancellous screws. The factory built angle of the plate fitted the metaphyseal— diaphyseal junction well and only fine intraoperative contouring was required. In distal tibal fractures, either pre contoured AO plates or medial tibial buttress plates were used after contouring. To avoid impingement, the expanded end of the 4.5 mm medial tibial head buttress plate must be bent to fit and wrap around the posterior aspect of the medial malleolus in distal tibial fractures. In the case of distal femoral fractures, we used the AO locking plate or DCS with side plate.

This technique allows a longer plate to be used. A long plate has several advantages. It distributes the stress over a longer length of bone, allows screws to be inserted at the most desirable intact bone away from the fracture site, and better assist the alignment of the distal to the proximal intact fragment. In addition, it allows us to successfully treat fractures extending into or close to the joints. Screws can be inserted at different angles, or inserted with the lag screw principle to effect inter-fragmentary compression. This versatility is not available with any intramedullary nailing device.[48]

Experimental works also reflect or explain the clinical results. Christian Krettek[23] in 1997 studied 12 human cadaver femurs with traditional plate osteosynthesis and biological plate osteosynthesis. The femurs with biological plating showed better periosteal and better medullary perfusion with less disruption of perforators and nutrient arteries. Baumgartel et al [15] designed a reproducible fracture for the sheep femurs and used three techniques to stabilize comminuted fractures – group A by anatomical reduction, group B treated by indirect reduction principles and group C had the same principles as group B but used an experimental plate with point contact and monocortically fixed screws. He found an overall improvement of fracture healing when biological principles were used.

These experiments and studies enable us to learn more about fracture healing, which will lead to optimal balance between biology and stability. Newer designs of implants help in achieving this optimal balance. Titanium

LCP – DCPs have revolutionized the outcome of these fractures treated by this method. The limited contact helps in better preservation of the vascularity. The tensile strength of titanium is closer to that of human bone when compared to the other metals.[48] This results in optimal biomechanical environment at the healing fracture site. It is also more biocompatible.

Thus explosion of technology and better understanding of the fracture healing help us to attain the optimal balance of stability and fracture healing as the famous anatomist - surgeon Schenk says **- "if the surgeon does something logical, bio does the rest".**

CONCLUSION

- Indirect reduction and minimally invasive percutaneous fixation appear to be very effective and have a proven value in the management of various spectrum of comminuted diaphyseal — metaphyseal fractures.

- Its greatest value appears to be in treating peri-articular metaphyseal and metaphyseo-diaphyseal comminuted fractures.

- It reduces the duration of surgery, intraoperative blood loss and hence post operative morbidity, which allows early rehabilitation and early return of function.

- It is also associated with less incidence of infections, non unions and implant failures and other complications.

- Accurate restoration of Limb length, rotation and alignment is possible.

- However the technique appears to be technically challenging. Hence early surgery, careful planning, intra-operative fluoroscopic monitoring and accurate contouring of the plate are essential.

- In case of intra-articular fractures, accurate alignment of the articular surface is imperative for good clinical outcome.

- The condition of the soft tissues and co-morbid conditions deserves to be respected.

Thus careful patient selection, meticulous preoperative planning, gentle and sensible soft tissue and bone handling, accurate contouring of plates and vigorous post operative rehabilitation and patient education appears to be the key to success of the procedure.

MASTER CHART

S. No	Name	Age	Sex	Type	Mechanism of injury	Associated injuries	Interval to surgery	Side	Time to union (weeks)	Implant used	Shortening (cms)	Angular deformity (Degrees)	Range of Motion	Complica tions	Outcome
1	Mr.Malaisamy	42	M	31-A3	RTA	Nil	3	L	10	DCS with Side plate	nil	nil	0-130	Nil	Excellent
2	Mr. Elumalai	45	M	31-A3	RTA	Nil	3	L	10	DHS with side plate	1 cm	nil	0-130	Nil	Excellent
3	Mr..suresh	29	M	32-C3	RTA	Nil	4	R	14	BDCP	nil	nil	0-150	Nil	Excellent
4	Mr.Sekar	32	M	32-C3	RTA	Nil	2	R	15	BDCP	nil	Varus -10	0-120	Nil	Good
5	Mr.Arulvezhan	37	M	32-C3	RTA	Nil	5	R	16	BDCP	nil	nil	0-140	Nil	Excellent
6	Mr.Anand	28	M	32-C3	RTA	Nil	1	L	12	BDCP	1 cm	nil	0-120	Nil	Good
7	Mr.Pushparaj	35	M	33-A3	RTA	Nil	3	R	13	DCS with Side plate	nil	nil	0-120	Nil	Good
8	Mr.Kathavarayan	32	M	33-C2	RTA	Nil	6	R	10	Distal femur LCP	Nil	nil	0-120	Nil	Good
9	Mr.Vijay rangachari	34	M	33-C2	RTA	Nil	2	R	12	Distal femur LCP	nil	nil	0-140	Nil	Excellent
10	Mr.Babu	40	M	33-C2	RTA	Nil	3	L	16	Distal femur LCP	0.5 cm	nil	0-130	Nil	Good
11	Mr.Sandeep	31	M	33-C2	RTA	Nil	2	R	12	Distal femur LCP	nil	nil	0-120	Nil	Good
12	Mrs. Rajeshwari	35	F	33-C2 Gr II comp	RTA	Nil	12	R	12	Distal femur LCP	2cms	nil	10-50	Implant failure	Fair
13	Mr.Albert	23	M	33-C3 Gr II comp	RTA	Fracture both bone leg (R)	12	R	12	Distal femur LCP	2 cms	nil	10 -90	Nil	Fair
14	Mr.Venkatesan	28	m	33-C3 grIII A comp	RTA	Nil	14	L	34	Distal femur LCP	3 cms	nil	0-30	non union	Failure
15	Mr.Thangamani	21	M	33-C3	RTA	Nil	1	L	14	Distal femur LCP	nil	nil	10-105	Nil	Good
16	Mr.Suresh babu	24	m	33-C3	RTA	Nil	2	R	16	BDCP	1cms	Varus - 10	10-50	Nil	Fair
17	Mr.Ranganathan	40	M	41-A3 Gr I comp	RTA	Fracture both bone leg (L)	3	R	12	L – buttress plate	nil	Nil	0-160	Nil	Excellent

S. No	Name	Age	Sex	Type	Mechanism of injury	Associated injuries	Interval to surgery	Side	Time to union (weeks)	Implant used	Shortening (cms)	Angular deformity (Degrees)	Range of Motion	Complica tions	Outcome
18	Mr.Jayaraman	34	M	41-A3	Fall	Nil	1	R	12	Locking T-buttress plate	nil	Varus - 10	0-120	Infection	Good
19	Mr.Elumalai	34	M	41-A3	RTA	Intertrochanteric fracture, bimalleolar fracture (R)	5	R	12	L-buttress plate	nil	Varus - 10	0-150	Infection	Excellent
20	Mr.Murthy	32	M	41-C2	RTA	Nil	1	R	10	locking T-buttress plate	nil	nil	0-150	Nil	Excellent
21	Mr.Palani	39	M	41-C2	RTA	Supracondylar fracture femur (L)	4	R	12	T - buttress plate	Nil	Nil	20-50	Infection	Failure
22	Mrs. Jayalaxmi	58	F	42-C2	RTA	Nil	4	R	12	NDCP	nil	nil	0-160	Nil	excellent
23	Mr.Venkatesan	45	M	42-C3	RTA	Nil	1	R	28	NDCP	nil	Valgus - 20	10-150	non union	Fair
24	Mr.Saravanan	15	M	42-C3	RTA	Nil	2	R	13	Locking NDCP	0.5 cm	nil	0-160	Nil	Excellent
25	Mr.krishnamurthy	38	M	42-C3	RTA	Nil	2	R	12	NDCP	nil	nil	0-160	Nil	Good
26	Mr.Vasudevan	45	M	43-A3	RTA	Nil	1	L	14	Distal tibial metaphyseal plate	nil	nil	DF-0-15 PF-0-30	Nil	Excellent
27	Mr.Prashanth	14	M	43-A3	RTA	Nil	1	R	10	T – buttress plate	nil	nil	DF-0-10, PF-0-20	Infection	Good
28	Mr.Koteeswaran	28	M	43-A3	RTA	Nil	2	R	10	Distal tibial metaphyseal plate	nil	Valgus-20	DF-0-10, PF-0-20	Nil	Good
29	Mrs. Mohana	36	F	43-C2	RTA	Bimalleolar fracture (L)	2	R	14	Distal tibial metaphyseal plate	nil	nil	DF-0-15 PF-0-25	Nil	Excellent

KEY TO MASTER CHART

M	-	Male
F	-	Female
RTA	-	Road traffic accident
DCS	-	Dynamic condylar screw
DHS	-	Dynamic hip screw
BDCP	-	Broad Dynamic Compression Plate
NDCP	-	Narrow Dynamic Compression
LCP	-	Locking Compression Plate

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Analysis of radiological and functional outcome of comminuted long bone fractures managed by Biological Plate Osteosynthesis

CASE PROFORMA

Name: Date of injury:

Age: Date of admission:

Sex: Date of surgery:

Occupation: Date of discharge:

Mechanism of injury:

Hemodynamic stability:

Diagnosis:

Classification:

Type of injury: closed / open

Associated long bone injury:

Associated head injury:

Comorbid conditions if any:

Consent for participation:

Initial splinting/traction:

Time interval to surgery:

Procedure done:

Type of plate used:

Proximal screws: cancellous

Cortical

Distal screws: cancellous

Cortical

Additional stabilization post operatively if any:

Intra op events and difficulties:

Immediate post op events:

Complications if any:

Blood transfusion:

Post operative alignment:

Limb length discrepancy:

Physiotherapy:

Quadriceps exercises

Knee mobilization

Continuous passive motion

Suture removal:

Advice on discharge:

Follow up:

Status of wound:

Range of motion:

Radiology:

Advice: