REVIEW OF LITERATURE
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Historical aspect:

Since time immemorial man has been beset by problems of accidents and injuries and has been trying to effectively cope with it. It will not be improper to say that the history of fractures and their treatment dates back to the advent of human race on this planet. Since no mode of recording the events existed in those times, there are no data on the methods of treatment practised during that period. Some glimpses of the knowledge that existed are, however, possible through the various scriptures that came into being subsequently.

The evidence of Egyptologists prove that, many thousands of years ago, broken bones were fixed to the splints, in much the same way, as is being done today.

In India earliest references to the subject of healing of bones are seen in Atharva-Veda (some 2000 yrs B.C.). Later on the Samhitas of Charaka and Sushruta, which were originally written about 1000 B.C. (Keswani, 1967), deal with the diagnosis and treatment of various types of fractures and dislocations.
Sushruta Samhita contains in it, essence of all that was known with regard to surgery and fundamental sciences closely related to this art. The orthopaedic treatment, which was based upon the rich experience of surgery, was rational and at times, ingenious. Sushruta, the father of surgery, described 6 types of dislocations and 12 types of fractures, while dealing with the diagnostic considerations (Nidansthana, second canto of Sushruta Samhita quoted by Singhal, 1977).

The different types of fractures described are:

1- Karkataka (Fracture with haematoma).
2- Ashvakarna (Oblique fracture).
3- Curnita (Comminuted fracture).
4- Piccita (Compression fracture).
5- Asthichhallita (Subperiosteal haematoma).
6- Kand Bhagna (Transverse fracture).
7- Majjan Targata (Impacted fracture).
8- Atipatita (Complete fracture).
9- Vakra (Green stick fracture).
10- Chinna (Incomplete fracture).
11- Patita (Crack fracture).
12- Sphatita (Fissured fracture).
The fractures, after a correct diagnosis, were treated among other things, with traction by means of a pulley (Chakra). The splinters (Shalya) lost or deeply seated in the organism were dextrously handled.

In the treatment of the fractures of lower extremities, mention is made of the Kapat-Shayana (Door Bed) or a fracture bed consisting of a plank of wood resembling the panel of a door. For fracture of the leg after making the patient lie, 2 pegs were fixed on both sides of knee joints and 2 pegs more were fixed on both sides of ankle joint and one peg was fixed against the plantar aspect of foot. Immobilization of fracture was deemed necessary and was affected by either one of the fourteen types of bandages (Bandha) or by means of bark splints and tying the limbs with bamboo strips. Charaka mentioned a bandage Kavalika (tow), so called from medicinal paste which was applied to the affected parts underneath the splints and fixed firmly after setting a fracture (Kawawani, 1977).

Apart from these references of ancient Indian medicine, no clear concept of fracture treatment, particularly of leg, is available till the middle of 18th century. Hippocrates, was probably, the first
to study the effect of muscular spasm on fractures and the uselessness of splintage without relaxing the muscles. The overlapping and shortening produced by it has been a constant headache for surgeons. To overcome these difficulties splintage became increasingly popular in the middle of 18th century. There were attempts to produce sophisticated splints as shown in Sauigny's instrument catalogue of 1798 (quoted by Gibson, 1976). Cramsey wire was popular too and the first illustration of such a wire mesh is found in 1845.

Amesbury, who practised in the first half of nineteenth century wrote several treatises on fracture and deformities, in one of which he described a splint for treating non union in the lower leg (Gibson, 1976).

Since then a number of treatments of fractures, particularly of leg have been decided from time to time.

The common methods of treating all types of fracture leg can be divided into following three heads:

1- Conservative method - Closed reduction followed by plaster immobilisation.

2- Open reduction and internal fixation with or without AO or ASIF techniques.
3- Percutaneous pinning followed by reduction and immobilization by either:
(a) Plaster or
(b) External fixator.

Conservative and open methods:

Until recently, closed reduction and plaster immobilization has been the most widely used and accepted treatment for fracture leg by various workers. But the consistent complications such as joint stiffness, muscle wasting, thromboembolic phenomena, disuse osteoporosis, renal calculi and hypostatic pneumonia which are invariably associated with prolonged immobilization, apart from the problems of malunion, malposition delayed union and non-union have led research workers throughout the world to devise newer methods which are comparatively free from these problems.

Oskar Lindon (1938), observed in a study of 52 cases, treated by conventional method, the average healing time of tibial shaft fractures to be 22.3 weeks with period of stay in hospital for 72 days. The average shortening was 1-2 cm. $5^\circ$ to $10^\circ$ of valgus in 13 cases (25%) and recurvatum in 19 cases (29.2%) was reported.
Robert Funstein (1945) reviewed 149 cases of fracture of both bones leg and found average healing time of 11.2 weeks for clinical union and 30.4 weeks for radiological union. Types of fracture made practically no difference in the rate of healing. Nicoll (1964) observed healing time of 16 weeks average being 12-20 weeks in tibial fractures treated with plaster. 25% cases had foot and ankle stiffness.

Edwards (1965), published a series of 492 tibial shaft fractures treated by above knee plaster cast. The result after one year followup were classed as good, fair and poor on the basis of pain, work capacity, limp, participation in sports, knee, ankle and foot motion and swelling over the lower leg. Longitudinal fractures showed 83% good and 7% fair results, while closed transverse fractures showed 95% as good or fair and 5% as poor results. Healing time was 9 months in closed transverse fracture and 14 months in open transverse fractures. The complications observed were skin necrosis, osteomyelitis and malunion in 4 cases (7.2%).

Slatis (1967) studied 198 tibial fractures, treated conservatively, with 50% of lower 1/3rd and 40% of middle 1/3rd, out of which 24% were compound fractures. Average healing time was 19.8 weeks. 90%
cases could resume work by 12 months. Closed fractures with little displacement and no comminution united well irrespective of the site of fracture.

Concerned with the problems of osteoporosis, joint stiffness, muscle wasting, post plaster oedema, and prolong period for which patient is kept away from his occupation, some workers went for initial open reduction and internal fixation, and compared the results with those of conservative treatment.

McLaughlin & Harrison (1949) studied 200 consecutive fractures of tibia treated by internal fixation and observed the complications which were :-

(i) Metal reaction.

(ii) Deep wound infection in 5% cases while the advantages observed were as under :-

1- Maintenance of length and axis of the long bones even in the presence of comminution.

2- Early achievement of good range of joint movements.

They reported that 90% patients with fracture of tibia and femur had full range of knee and ankle movement after open reduction.

Lottes (1952), while evaluating the results of 176 fractures of tibia, observed that weight bearing
at the end of 5 months of treatment was seen in 74%, 15% and 6% patients treated by nailing, plating and plaster immobilization respectively. Incidence of non union was 23.7% with plating and 10% with conservative method of treatment, while in none treated by nailing. Other complications, which were mainly seen after plaster treatment were, shortening, rotation and thrombophlebitis.

Blocky (1956), emphasized more on the advantage of rigid fixation by doing internal fixation in fractures. In his opinion plaster immobilization can never give rigid support, no matter, how well the plaster is given and also that plaster can never give that degree of fixation which is essential for union in ideal circumstances.

Solheim (1960), studied 500 tibial fractures treated by closed reduction and plaster cast and open reduction and internal fixation. Healing time was least in patients treated by closed reduction and plaster. Compound fractures took maximum time to unite, while transverse fractures took least time to unite. The incidence of knee stiffness was 23% when period of immobilization was more than 16 weeks, while it was 8% when it was less than 16 weeks. Overall incidence of swelling was 8%.
Michael Alme (1962), reviewed 200 tibial fractures treated by above knee plaster with absence from work for 22 weeks, while on the other hand, in fractures treated with intramedullary nailing the average time of absence from work was 13 weeks.

Despite the obvious advantages of good reduction and early mobilization internal fixation carries a definite risk of infection which can range from a mild degree to involvement of whole of the diaphysis. According to Burwell (1971), the disadvantages of internal fixation are:

1- Delayed wound healing.
2- Sepsis
3- Loosening of implant, thus loss of rigid fixation.
4- Delayed union and nonunion.
5- Metal reactions.
6- Fat embolism and venous thrombosis.

This is obvious that while treating a fracture both bones leg, both the conservative and internal fixation methods have their own advantages and disadvantages and some times the disadvantages outweighing the advantages. At this stage treatment by passing percutaneous pins in the shaft of the long bone and after reducing the fragments, immobilizing them in either
a plaster cast or a external fixator have their own definite role.

Percutaneous pinning followed by reduction and immobilization by rigid external metal frame:

External fixation, refers to a method of immobilization of fractures which employs transfixing pins in bone, attached to a rigid external metal frame or incorporated in plaster.

The first external fixation device, for the treatment of fractures, was described by Malgaigne in 1851, who employed claw like external fixation device for the first time (Ruskin 1980).

On 1897, Clayton Parkhill, an American surgeon, inserted screws from cortex to cortex and then connected them with an external clamp, in treating difficult fractures of femur. This apparatus came to be known as Parkhill Bone clamp.

In 1904 Codéville employed the principles of pins in leg lengthening operations, he connected the pins with external bars without the use of plaster.

After the advent of Steinmann pins in 1907 by Steinmann (Steinmann 1907) various interpretations if
its adoption, specially with regard to external fixation of the pins with plaster or mechanical devices were published by many workers.

The first surgeon to use a device similar to present designs was Alvin Lambotte of Belgium who published his work in 1907. This worker used percutaneous half pins with a rigid external frame on the femur and other long bones which is remarkably similar to certain presently available designs.

Boehler's contribution during this period was outstanding. His use of a simple reduction fracture frame and screw traction apparatus, in conjunction with pins or wires introduced a new era in accepted fracture treatment. His persistent efforts and successes were chiefly responsible for the gradual elimination of pin phobia, held then by many surgeons.

In 1931, Stader, while working in the field of veterinary surgery, was worried over the inadequacy of the methods in use for treating the fracture shaft of long bones in dogs. Plaster was not tolerated by the animals. They frequently destroyed it by constant biting and tearing, or the plaster was disintegrated
by constant soiling with excreta. Traction and counter traction in a modified Thomas splint had been used extensively, but the degree of fixation obtained was usually insufficient and pressure necrosis from the rings often defeated its continuous use. Stader then used two half pin units in each fragment, connected by an adjustable metal bar. Thus, he could usually achieve anatomical reduction and it did not seem to annoy the animal and was well tolerated by them until union of fracture had occurred. Till may 42 he had treated over 1200 fractures in dogs, with the results obtained being uniformly good and far superior to the older methods of treatment.

In the 1930's widespread efforts were undertaken to develop methods of external fixation. Perhaps the best known were Roger Anderson, Otto Stader, H.H. Haynes in the United States and Raoul Hoffmann in Switzerland. Many of these attempts were made with supplementary plaster casts although in the presence of open wounds the cast was frequently not used.

Lewis and Bredenboch (1942), had the opportunity of seeing the Stader splint applied to a police dog for fracture shaft femur. They were impressed by the ease of application, the prompt and
accurate reduction obtained and the simplicity of
the instrument. They decided to have a larger model
or splint for use in human beings.

In October 1937, the first patient named
W.W. was treated by this method for fracture of both
bones leg in fourth division of Belleme hospital,
New York. Patient was able to bear the weight on
injured limb in two weeks. During the period between
1937 and 1942, a total of 20 patients were treated
by this method with uniformly good results, except
in 3 patient where infection around pins occured, but
properly subsided after removal of pins. The splint
was kept in place untill bony union had occured which
varied from 8 to 16 weeks.

Shear and Kreus used Stader splint in 157
cases of various types of fractures. They analysed
84 cases of simple fractures and 21 compound fractures
of tibia and fibula. No pin tract infection was
reported. None of the cases passed in to non union.
Knee and ankle movements restored normally and no
physical therapy was required. They advocated the
Steller splint as an ideal device for treatment of
compound and comminuted fractures of tibia.
Nasnet, in 1949, after his observations, enlisted the advantages of this method as follows:

1- It presented the more perfect and accurate method for obtaining reduction.
2- It avoided firm fixation.
3- It avoided distraction.
4- Permitted early ambulation.
5- It was valuable in cases of compound fractures where dressing, skin grafting and bone grafting can be carried out without disturbing the fragments.

During the period between 1942 and 1949 a total of 237 tibial fractures were treated by Maden with this method. He reported end results in 206 of them. In most cases he used two through and two half pins. An extra half pin was added to prevent side slipping. If the general condition of the patient was good, ambulation on crutches was started on next day of fixation. Full weight bearing was deferred till the evidences of clinical and radiological union. The average period for union of simple fractures was 16 and half weeks, and for compound fractures 22-34 weeks.

Five percent of the patients developed minor irritation around pin tract. A few patients had definite infection but without involvement of bone. Four patients
showed small sequestra around the pin sites. The wound healed following their removal. One patient had low grade infection in tibia with persistent drainage. One patient had a pin clamp broken after one month. The fracture was displaced badly and required open reduction bone grafting and repinning. One patient had sloughing of paroneal group of muscles with lateral popliteal nerve involvement but this improved with time. Two cases of simple fracture and four cases of compound comminuted fractures with bone loss passed into nonunion, which were later treated by bone grafting.

By 1950's, however, external fixation had fallen into disrepute because of high rate of complications reported to accompany the use of device with poor adjustability and inadequate rigidity (Anderson Roger, 1943; Davis, 1943; Naden, 1949), however these complications could be attributed to the poor quality of the external fixator itself. Although success was reported, pintract infection and delayed union frequently occurred.

In 1950, a retrospective study was conducted by the committee on fracture and traumatic surgery of the American's academy of orthopaedic surgeons, to
evaluate the external fixation method of treatment. Of 359, 287 surgeons felt that this method had not advantage over other methods. The disadvantages listed were soft tissue infection at fracture site, ring sequestra and osteomyelitis followed by nonunion, mechanical difficulty, pain conversion of simple fracture into compound fracture and difficulty in obtaining and maintaining reduction. Pintract infection was the chief cause of discontinuing the use of external fixation.

External fixation was advocated by Charnley in 1944 for compression arthrodesis of knee. Hoffman in 1938 developed a four poster double frame external fixation device which was later modified by Vidal in 1973 and is still one of the latest available.

Increasing vehicular accidents resulting into increasing incidence of compound fractures of leg and their unsatisfactory treatment by the conventional plaster method or internal fixation has been the most probable cause of reviving the orthopaedic surgeon’s interest towards the external fixation method of treatment recently.
Karlstrom treated from 1970 to 1973, 28 severe open tibial fractures and experienced excellent or good results in 17 patients. Average time for full weight bearing without support being 7.9 months.

Burke et al (1977), reviewed 28 patients with a total of 26 fractures of long bones and 6 pelvic fractures treated with the Hoffmann external fixation apparatus. All the extremity fractures were compound with varying degree of soft tissue injury including seven with neurovascular complications. In these patients a total of 54 secondary procedures consisting of debridement, skin grafting and bone grafting were performed with the apparatus in place. They concluded that the device offered advantage which far outweighed the objections to its use in the management of compound fractures of long bones and infected nonunion.

Edward (1979), reported the study of 44 open tibial fractures in patients of multiple trauma. 73% of the cases had bone loss or major comminution, 55% had soft tissue loss. After initial debridement a double frame Hoffmann apparatus was applied and fracture reduced. The wound was packed, left open and limb was suspended from an overhead beam. Once the wound was
healed the external fixation was removed and the weight bearing cast was applied.

In this series the result using external fixation were clearly better than those treated with other alternative methods. Fifty seven percent of cases achieved primary union with good tissue coverage and had no related complication. Bone grafting was required in 30 percent cases, muscle flap in 30 percent and skin grafts in 48 percent. Initial union was evident at 4 months and complete at seven and half months. 23 percent of the tibia developed osteomyelitis and 30 percent of cases had at least one pintract infection which cleared after pin removal. A few cases developed ring sequestra requiring curettage. Nevertheless pintract infection remained a common problem even with enlightened Hoffman apparatus.

Vidal et al (1979), also presented few examples of open fractures with loss of bone substance. They considered Hoffman’s device to be indispensable in the treatment of fractures with loss of bone substance. It permitted easy surveillance of wound, was completely versatile and sufficiently stable. This method, judiciously executed has enabled them to save numerous limbs which would have otherwise been amputated.
Lawyer and Lubber (1980) used the four poster double frame developed by Hoffmann in 1938 and modified by Vidal (1973). According to them the traditional problems in the treatment of fracture long bone includes:

(i) Devascularization either traumatic or iatrogenic.
(ii) Instability leading to loss of reduction.
(iii) Bone loss or distraction.
(iv) Infection.

Properly applied external fixation can minimise and in most cases can overcome these problems.

In their own 34 complex tibial fractures, otherwise considered to have a poor prognosis, they achieved anatomical reduction in 25 fractures, while, in most of the cases closed reduction was tried, compression by Hoffmann apparatus could only be applied in transverse fractures. In oblique fractures cortical lag screw across the fracture site was used. In severely comminuted fractures or with extensive bone loss, apparatus was used to maintain the length of limbs till bone grafting was done. The average time of union was 5.8 months, which appeared to be directly proportional to the accuracy of reduction. 25 fractures
which could be anatomically reduced and compression
was applied, united in an average time of 5.1 month.
In compound fractures union time was delayed to 8.3
months as compared to 5.3 months taken by closed
fractures.

In this series, primary bone healing was
achieved when the fracture was anatomically reduced
and movements at fracture site were minimum. This
was shown by clinical stability in two or three
months without evidence of visible callus on roent-
genogram.

Laywer and Lukber, advocated the philosophy
of anatomical rigid fixation of fractures, which they
believed was possible by external fixation with
inflicting minimal vascular damage.

Recently Edge and Dunham, used portsmouth
external fixation device to treat 35 complicated
tibial fractures. 90% of their patients achieved
union. 16 of the patients developed mild pintract
infection. None of their patients developed joint
stiffness.

Though most often used for treating fracture
legs, the external fixation has been tried in the
treatment of other bone fractures as well as the pelvic fractures.

Kuderna (1977) and Saligson (1978), used it for compound comminuted fractures of femur and pelvic bones and found good results. Kasahim et al (1978), and Burney et al (1979), used external fixation device for treating simple and complicated fractures of humerus.

Percutaneous pinning followed by reduction and immobilization in a plaster cast:

In all probability Roger Anderson (1934) seems to have conceived this idea. He devised a new apparatus, a small fracture table only 20 inches long, also called as fracture robot, with mechanism so adjustable that all the discrepancies such as rotation, angulation and imperfect traction were overcome with an unremitting mechanical force. After reduction of fracture he used to incorporate the transfixing pins in a plaster cast. He allowed the patient for crutch walking on second day, but body weight bearing was not allowed for the first few weeks.

In compound fractures with extensive soft tissue injuries the leg was left completely exposed in the splint for as many weeks as necessary while the wound and the fracture were receiving simultaneous repair.
According to him, double pin or wire transfixion provides all the benefits of skeletal traction plus those of skeletal countertraction. Both the upper and the lower fragments are individually under direct control during apposition of the fractured ends. Furthermore, by literally nailing the bones to the cast he gained definite insurance against any later displacement.

From 1933-38, 259 leg fractures were treated by Triswold and Holmes by pins incorporated in plaster. The results obtained were good.

In 1960 John R. Moore of Philadelphian Pennsylavania treated unstable fractures of long bone by application of a carefully welded plaster cylinder which was supplemented by cutting two small circular windows over both the upper and the lower fracture fragments and inserting half pins, preferably into cortical bone well away (two to three inches) from the fracture site and two inches apart. After insertion the pins were incorporated in the plaster and a cylindrical section of the cast was removed from over the fracture site. Reduction was then repeated and when it was found to be satisfactory the two sections of the cast were reattached to each other with plaster.
These pins were stainless steel and 2 mm in diameter; they passed through the skin, proximal cortex and medullary cavity and projected through the opposite cortex 3-4 mm. They were called half pins because they did not traverse the opposite soft parts. They could be removed and reinserted at different levels if they produced irritation. These small half pins and plaster cylinder could easily be applied to proximal and distal fragments in difficult reductions, permitting precise manipulation of fragments. The pins could be left in or removed depending upon the stability of the fracture reduction. The author stated that the use of these half pins solved for him the problem of unstable fractures.

In 1964 Nicoll E.A. in his survey of 705 cases of tibial shaft fractures stated that if proper safe guards are adopted against recurrent displacement in unstable fractures the problem of shortening and residual deformity can be avoided. He achieved this, quite simply, by transfixing the upper fragment with a pin incorporated in plaster. According to him it is not necessary to transfix both the fragments if the plaster in well moulded round the ankle.

In 1966, Vincent A. Scudera, Andre Birottte and Joseph Giallenella did a 5 years study of
consecutive lower third tibial shaft fractures in adults treated with percutaneous multiple pin fixation, closed reduction, a short leg cast and immediate weight bearing.

They did a review of the results of 75 consecutive fresh displaced lower third fractured tibias in 73 adults. The ages of the patients ranged from 21 to 78. 54 were male and 13 were female. The youngest male patient was 21 and the youngest female was 22 years old. The oldest male was 75 and the oldest female 78. All of the fractures were in the middle and lower part of tibia. Associated fractures of the fibula was present in 63 cases. There were 60 closed fractures and 15 open fractures. The open fractures had wounds ranging from puncture to extensive lacerations of the skin, fascia, muscle and periosteum. Fractures were freshly displaced and were accompanied by moderate soft tissue trauma. All cases were manipulated under general anaesthesia or spinal anaesthesia.

They found that mean time for healing was 16\(\frac{1}{3}\) weeks. In 92 percent it ranged between 16-17 weeks while in 8 percent of the cases the healing was 20 weeks or less. Oblique fractures healed faster
than all other fractures, regardless of whether they were open or closed. Commnunited fracture healed slower than the remaining fractures. Uncomnunited closed fractures were stable at 8 weeks and radio-
graphically united at 16 weeks. Closed commnunited fractures were stable at 10 weeks and radio-
graphically united at 17 weeks. Open uncomnunited fractures were clinically united at 9 weeks and radio-
graphically healed at 20 weeks.

There were no instances of nonunion or delayed union. No additional surgery such as bone
grafts or fibular osteotomies were required. There was no evidence of shortening. Secondary inflammatory reaction about 2 pins occurred in another case, however,
osteomyelitis did not occur and healing was uneventful in 10 days. No refractures were observed in this series.
Preserved normal knee motion was associated with early restored ankle and foot motion. Adverse reactions,
such as osteous infection and pseudoaneurysm were not observed.

In 1966 Anderson L.D. and Hutchins, W.C.
reported their experience with a method of closed
treatment of fracture of the tibia and fibula which they had used during the previous several years. The
treatment consisted of Kirshner wires or Steinmann pins through the tibia, closed reduction of the fracture and incorporation of the wires or pins into a plaster of paris cast. They stated their belief that this method had certain advantages over closed reduction alone in difficult, unstable fracture of both bones of leg. Also it avoids the known complications of internal fixation inherent in the use of plates and screws, screws alone or medially fixation.

In 1974, Goren Karlstrom and Sven Olerud published a paper on critical evaluation of treatment alternatives for fractures of the tibial shaft. They found that in most of the severe fractures which according to Ellis's classification include those tibial fractures which are caused by direct high energy violence, stable transfixation by the Vidal Adrey method is the treatment of choice. Soft tissue injuries are easily managed and reconstructive skin and soft tissue surgery can be performed parallel with the fracture treatment e.g. myoplasty to cover the bone surface and application of a split skin graft. Further, there is sufficient stability for movement exercises and in some cases even for weight bearing. By this method amputation which might
otherwise be deemed necessary can be avoided and in addition excellent functional end results may even be achieved.

According to the authors the above described advantages are not provided by customary transfixation with pin and plaster cast which, however, is a mechanically less complicated method.

In 1974, Nicoll E.A. while discussing closed and open management of tibial fractures stated that the displaced, unstable fracture which is unstable after reduction because of comminution or the shape of the fracture line or a combination of both can be stabilized by the simple expedient of inserting a Steinmann pin through the upper fragment at the level of the tibial tuberosity and including the pin in the plaster. According to him a second pin can be included through the lower fragment or the calcaneum, but with a well moulded plaster around the ankle this was usually unnecessary. A single pin was used to stabilise the reduction and had the further advantage of preventing that rocking movement of the upper on the lower fragments that inevitably results from quadriceps drill in the plaster.
In 1974 itself, Lewis D. Anderson, Wiley C. Hutchins, Philip L. Wright and Jere M. Disney published their findings on the treatment of fractures of the tibia and fibula by casts and transfixing pins. They tried this method on a total number of 264 patients with 250 fractures of both bone leg. 31 patients were lost to followup and this left a total number of 203 patients.

The fractures included in this study were unstable, committed and open fractures treated during the course of study at the Cambell clinic and the city of Memphis hospital in patients over 14 years of age. 198 out of the 203 fractures united without additional treatment (95.2%). There were 5 delayed unions (2.4%) that required Ilizarov type bone grafting without internal fixation, and there were 5 nonunion in which some form of internal fixation was used along with iliac bone grafts (2.4%). Out of the 203 fractures 96 were open (46.9%) and 107 (53.1%) were closed. 103 (49.9%) had mild to moderate comminution. 46 (22.1%) had severe comminution and 5.8% were segmental.

Out of the 10 patients it was found that 9 out of 10 had associated injuries of a major nature
including fracture of spine, femur and upper extremity which prevented the institution of weight bearing at the time of wires or pins removal.

The average time to full weight bearing without support for the 198 fractures that united without additional treatment was 7.5 months. For the 10 patients with delayed or nonunion the average time to full weight bearing without support was 14.9 months. Of the 184 patients whose X-rays were available 101 (54.9%) were classified as excellent and 61 (33.1%) were classified as good. Thus, 80% had a very satisfactory result with less than half inch of shortening and less than 10° of angulation in any direction. 10 patient (9.3%) were classified as fair and 4 (2.2%) as poor.

Only 5 patients developed minor infections of pin tracts. All of these subsided when the pins were removed and none required sequestrectomy.

The initial cast was removed between 5 and 8 weeks depending upon the degree of instability of the fracture. The Steinmann's pin were removed and a snug long leg walking cast was applied. Progressive weight bearing began as soon as the cast had dried.
provided there were no associated injuries that
precluded weight bearing.

Authors found that complications such as
shortening and angulation were significantly prevented
by using this method.

They also found this method very helpful in
the management of open fractures. A window was cut
in the cast for dressing or debridement of the wound
as necessary without losing reduction of the fracture.
The increased stability afforded by the pins also
helped in controlling infection.

EXPERIMENTAL STUDIES:

Although experimental studies to study the
fracture healing by use of an external fixator device
are very few, the literature abounds with reports
studying the effect of familiar types of treatments
of fractured limb.

However, as outlined by Mazet in 1943, the
following advantages of external fixation are also
reported to have a favourable effect on fracture
healing.
(i) Perfect and accurate reduction.
(ii) Firm fixation and maintenance of reduction.
(iii) Provision for compression.
(iv) Avoidance of distraction.
(v) Early mobilisation and weight bearing.
(vi) Rapid soft tissue healing in cases of compound fractures.

According to Anderson (1965), there are 3 areas of osteogenic potential in healing of any fracture.

(i) The periosteal reaction.
(ii) Endosteal or Medullary callus.
(iii) Fracture haematoma.

The cortical fracture ends are a fourth possible area of osteogenic potential.

In the fractures, treated with inadequate fixation or those with marked overriding and angulation of fragments, the periosteal reaction and endosteal callus can be of little help in their healing. Union in these fractures is almost entirely by massive formation of cartilage within organising fracture haematoma and gradual conversion of this cartilage to bone by enchondral ossification.
Fractures treated with medullary nails must unite by peripheral callus because the nail blocks the endosteal callus formation. Union is therefore entirely peripheral and takes place by bone formation in fracture haematoma, bridging the gap between the periosteal reaction of two fragments. There is little doubt that the insertion of medullary nail is basically unphysiological because it destroys the medullary blood supply and a large part of blood supply of cortex, and prevents formation of endosteal callus. Delayed union and non-union are the rule when the nail was inserted loosely or became loose (Anderson, 1965).

On the other hand the plate and screw fixation produces less damage to the medullary and cortical blood supply. The peripheral bone formation from periosteum and bone formation in fracture haematoma are not prominent. While some authors have deemed periosteal callus more important (Phemister, 1935; Callie, 1919; Nas and Harris, 1956; Nilsson, 1961; McLean and Urist, 1961), others, have thought that endosteal callus formation is more important for fracture healing (Enne King, 1940; Anderson, 1965; Rhinelander, 1974).

There is no such problem with external fixation as it does not hamper with either medullary vascular system or the normal effective blood flow of the cortex.
It also does not drain the fracture haematoma which is responsible for primary bone union.

Rhinelander in 1966, while studying the healing by microangiography in dogs, observed that in cases of stable reduction of fragments, the medullary circulation, crossed the fracture gap within at least 3 weeks but when the reduction was unstable, the chief medullary arteries remained blocked at the fracture fibrocartilage for a longer period. He also reported that when the fracture fragments were stable, osseous callus at 3 weeks had united the portion of living cortex across the fracture line.

According to Verma and Mehta (1967), perhaps continued mobility, following loose fixation, is responsible for prolonged relative or complete avascularity at the fracture site, by hampering with the mobility is reduced by formation of primary fibrocartilagenous callus, favoured due to low oxygen tension caused by relative ischaemia. When the fracture is rigidly immobilised the ingrowth of capillaries can take place more rapidly and hence there is direct bone formation.

Verma and Kumar (1973), studied in an experimental study, fracture healing under different types of
fixation taking rabbits as experimental animal. They divided 24 animals into 4 groups of 6 animals each. After producing a fracture in the midshaft of tibia manually, every group was treated with a different type of immobilisation.

In the first group of animals, treated by a long leg plaster cast, healing of fracture was achieved in 4 weeks time. Criteria of union being radiological as well as clinical. The callus was well consolidated by 4 weeks. Measuring the tensile strength of the callus they observed a rapid increase in tensile strength after 4 weeks. The tensile strength of callus of 2 weeks was 6.4 kg., which reached to a maximum of 12 kg. at the end of 6 weeks. Reductions of fractures were more or less satisfactory, but anatomical reduction was exception. No primary union was achieved at the fracture site.

In next group treated by unstable intramedullary fixation by a loose Kirschner wire, thus allowing movements at fracture site, though the reduction achieved was almost anatomical, clinical and radiological union occurred after 5 weeks with a large spindle shaped peripheral callus which showed poor consolidation.
The fracture line remained visible radiologically till the end of 6th weeks. The maximum tensile strength of the callus obtained was 7 kg. at the end of 6 weeks.

The animals treated with intramedullary stable fixation showed clinical and radiological union after 4 weeks, with a minimal of well consolidated peripheral callus. Fracture line underwent a gradual fading and was not visible radiologically from 4th weeks onwards. Tensile strength of the callus which was 6 kg at the end of 2 weeks, reached to a maximum of 9.5 kgs. at the end of 6 weeks. The tensile strength showed a rapid increase after 3 weeks. Histologically minimal of cartilage was found from the end of 5th weeks. Similar are the observations of Anderson (1965), Varma and Mehta (1967), and Lottin (1968).

Lane (1979), and Li (1979) studying effect of immobilisation on the healing fractured tibias of rats observed maximum callus size in mobilised tibias at the 4th week. Fracture lost its radiolucency by 7 week. In this model the firmly fixed and immobilised limbs developed a very sparse external callus, with negligible amount of cartilage. Moreover the bone healed by direct membranous bone formation.
Compression over the fracture site also helps in promoting bone union. (Basset, 1962; Anderson, 1965; Simmons, 1980). Compression over the fracture site can be very effectively provided by means of external fixator device without disturbing either the periosteal or medullary circulation and without draining the fracture haematoma.

Basset's (1962) work on tissue culture has shown that primitive mesenchymal cells exposed to high oxygen concentration and tension develop into osteoblasts. Low oxygen tension or distraction produced fibroblasts.

Anderson (1965), holds that compression appears to be beneficial in cortical bone fracture because it increases the rigidity of fixation by impacting the bone ends and the space between bone ends, which must be bridged by new bone, is narrowed. He achieved 100% union, of experimental ostectomies, in animals sacrificed 6 weeks after the operation, with direct cortical healing of ostectomies.

Bensch and Willenberger (1964), achieved healing of ostectomies in dogs fixed rigidly with compression plate without any externally demonstrable callus.
Verma and Mehta (1967), in their experimental studies of fracture healing with different types of fixation observed, that with a stable fixation, healing occurred easily by a direct intra-membraneous new bone formation with little peripheral callus. Whereas with loose fixation there is greater amount of peripheral callus formed by enchondral new bone formation.

Hicks (1969), pointed out that, the amount of callus varies with the degree of rigidity involved. Similar were the observations of Hutmacherreuter (1969).

Strength of callus has been shown to be inversely proportional to the size of callus (Piekarski, 1969). He explained the low strength of the callus having a large cross section by the greater porosity.

Experiments of Russain (1971), further support the observation of the previously reported studies, regarding the effect of absolute reduction, firm fixation and compression over the fracture of long bone by external fixation. He observed that if provided absolute rigid fixation and accelerated the process of fracture healing.
Sahu and Sharma (1984) conducted a study on rabbits to evaluate and compare the efficacy of external fixation with that of conservative plaster cast.

They performed experiments on 90 adult rabbits with weights ranging from 1.0 to 1.3 kgs. 9 animals were excluded from the study leaving 90 animals for study. Animals were divided into 2 groups of 45 each. Closed fracture of right leg was produced in both the groups by applying angulatory force. Group A was treated by reduction and immobilization in long leg plaster of paris cast. Group B was treated by reduction and immobilization with application of an external fixator.

9 animals from each group were sacrificed every week from 2nd week up to 6th week. Apart from detailed clinical examination, macroscopic, radiological and mechanical examination (Tensile strength, compression strength and angulatory strength) were carried out after dissecting the bone out of the soft tissue carefully.

They concluded that, on the whole as compared to plastered group, external fixator not only helped to achieve an accurate reduction, it also maintained a rigid fixation of fracture fragments leading to an early and better quality of union with a much smaller
but stronger callus. Complications observed were also much less with the use of external fixator.

Studies on the effect of external fixation and pins and plaster over the fracture healing and how exactly they promote fracture healing and their mutual comparison are rather lacking and further research in this field is absolutely necessary.