REVIEW OF LITERATURE
HISTORICAL BACKGROUND

Earliest reference to the subject of healing of bones is found in Veda (2000 B.C.). Samhitas of Charak and Shushruta (1000 B.C.) deal with the diagnosis and treatment of various types of fractures and dislocations.

Evidence of Egyptologists prove beyond doubt that many thousand years ago, various kinds of splints were used to support broken bones. Hippocrates was probably the first to study the effect of muscle spasm on fractures and its usefulness in splintage.

Splintage for fracture treatment became popular in middle of 18th century. First illustration of crammer wire as splintage was found in 1745.

Methysen (1852) a Dutch Scientist was the first to use and popularise plaster of paris bandage, and recommended that fractured bone were to be immobilised with one joint proximal and one joint distal till complete union occurred. Over the years a number of treatment are evolved for the management of a fracture. The common treatment for all types of fractures may be divided into following heads.

A. Conservative Methods
   - Close reduction and plaster of Paris immobilisation.
   - Cast bracing.

B. Operative Methods
   - Open reduction and internal fixation.
- Encirclage wiring.
- Screw fixation.
- Plate and screw fixation.
- Intramedullary nailing (Open or closed).
- Interlocking Device (Dynamic or static).

**MANAGEMENT OF OPEN FRACTURES**

The Greeks provided the first documented scientific basis for surgery and medicine. There are early reports, dating back to 2930 BC, of the first use of crutches as depicted on a carving on the entrance to kirsouf's tomb. Mummies of 2500 BC have limbs splinted quite credibly. However, Hippocrates' writing in the fourth century BC are the first accounts of the early medical treatment bearing any true scientific worth.

Hippocrates basic principle in medicine centres on the healing power of nature, specially concerning open fractures. Hippocrates deals with fine concepts directed towards aiding this healing power of nature. They are (1) Antisepsis (2) Bandaging (3) Reduction maneuvers (4) Splinting (5) Traction. For antisepsis he suggests a create mixed with pitch to be applied to the wound. Hippocrates is also well known for his concept of cautery of wounds. He states "Diseases not curable by iron (the knife) are curable by fire". The harmful effects of producing more divitalized tissue in the wound was not recognized during time of Hippocrates.
For bandaging Hippocrates described the use of wax, starch and clay on the bandages to provide stiffness around the wound. For reduction maneuvers he used a blacksmith's tongs to reduce protruding portion of bones in open fracture. Another device used by Hippocrates for both splinting and traction employed leather bands wrapped around leg above and below the fracture site held in "distension" by four elastic hollow rods placed between bonds.

In the first and second century AD Galen stated that 'Coctio' or suppuration is essential for wound healing. This idea persisted in the twelfth century, becoming Roger's concept of Laudable Pus.

Theodoric of Salerno (1205-1295) opposed the doctrine of Galen and Roger. He stood out in his day as a pioneer of simple dry wound care.

Pare and Sixteenth century, refuted Hippocrates doctrine of cauterizing wounds, used to pour boiling oil into the gunshot wounds of soldiers in the battle. It is said, Pare ran short of his supply of oil and was forced to treat these gunshot wounds (assumed to contain poisonous substance) without the use of oil. Contrary to his expectation, these wounds did very well.

Already, early in literature of surgery of open fractures, two essential therapeutic principles were to be found which appeared to have impressed the experienced, traumatic surgeon repeatedly debridement and immobilisation. The term "debridement - unshackling" was not
correct as used in the sense 'debridement' i.e. removal of necrotic shattered remnants.

Joseph Desault in the early 1760's was the first to define debridement as a deep incision into the wound for exploration and to provide drainage. The use of debridement was popularized by B.D.J. Lerry, the surgeon in Chief to Napoleon's ground army. He advocated for early debridement of wound. He believed that the prognosis of compound fractures was related to the time interval between injury and treatment.

On August 12, 1865, Joseph Lister treated open tibial fracture of an eleven year old boy. Carbolic acid was used by to purify the drains and to heal the wounds. Joseph Lister's contribution was a principle that have less trust in antibiotic, let no bacteria enter and establish themselves in tissues. Antisepsis for every instrument, non touch for every technique, asepsis for every surgical principle.

An unforeseen ill effect of Lister's influence was that idea of miraculous substances reappeared and the principle to debridement was relatively forgotten.

We quote the surgical experience of C.W. Billroth from Zurich (1860-1887) of 93 patients with open fracture of lower limbs, 57 of fractures healed, 36 patients died, Of 16 patients with open fractures of diaphysis of the femur 6 healed, 10 died. Of the 93 lower leg patients, 28 had amputation and 65 had plaster bandage with minimal debride-
iment of these 65 patients 15 died mainly from wound infection and 20 out of amputed died. Billroth, the founder of gastric surgery said that, "I can assure you that from my own experience, none of my most successful surgical cases has pleased me as much as the successful cure of a severe open fractures.

A little later, the classic master of wound healing Conrad Brunner, insisted convincingly on exact debridement with wide exposure, spreading out the wound margins, irrigation with hydrogen peroxide during operation and freshening up damaged tissue. The wounds were loosely packed with Iodoform gauge and left wide open immobilisation was affected by plaster of paris cast with a window.

Winnete Orr from his experience of world war I formulated the following principles of management of open fractures:

1. Completely primary debridement.

2. Primary reduction utilizing adequate traction to achieve reduction.

3. Complete immobilisation.

4. Provision of drainage beneath the cast.

5. Infrequent dressing change.

Till recently conservative methods of closed reduction followed by plaster immobilisation was the method used in most cases of fracture leg and today also it is the method of choice in most simple, stable type of fractures.
Oscar Lindon (1938) observed in a study of 52 cases treated by conventional method, the average healing time to be 22.3 weeks with period of stay in hospital for 72 days. The average shortening was 1-2 cm, 5 to 10° of valgus in 20 cases (38.4%) and varus in 13(25%) cases and recurvatum in 19(29.2%) cases was reported.

Griffith (1942) analysed 249 fractures treated by above knee plaster and found mean time for union 16.5 weeks.

Ellis (1958) treated 315 tibial shaft fractures and divided them into following 3 groups:

1. Minor severity - undisplaced fracture, minor degree of compound fractures with little comminution.

The recorded average healing time as 10, 15 and 23 weeks in the three groups, respectively. Site of the fracture did not alter the healing time and union was rapid below 16 years of age, but reported limitation of knee flexion, foot and ankle motion and pain in foot and ankle as important disabilities.

Jackson and Mecwab (1959) also recorded almost similar findings.

Nicoll (1964) observed healing time of 16 weeks in 705 cases, range being 12-20 weeks. The intact fibula hastened the healing time. 25% cases had foot and ankle stiffness.
Weissmann et al (1966) reported average union time of 19.4 weeks in 200 cases, with complications of delayed union and non-union in 12% and 5% cases respectively.

Slatis (1967), Hougland (1967) and Burwell (1971) emphasized that closed methods of treatment of such fractures is by far the safest method.

Concerned with problems of osteoporosis, joint stiffness, muscle wasting, post plaster oedema and prolonged period during which patient is kept away from his occupation some workers went for initial open reduction and internal fixation.

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 none with nailing. Other complications which were mainly seen after plaster treatment were shortening, rotation and thrombophlebitis.

Clifford emphasized more on the advantages 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.
INTRAMEDULLARY NAILING

In the beginning of this century a series of efforts done by general surgeons to overcome the handicaps of non-operating method of fracture treatment by adopting a more aggressive surgical approach to the injured tissue of musculoskeletal system.

Kuntscher (1940) added internal splintage by intramedullary nail to the arsenal inter-fragmenting and axial compression osteosynthesis, and then extended its indication by adding reaming of medullary cavity in metaphyseal region.

In 1958, some fifteen Swiss general and orthopaedic surgeons met and discussed the status of results obtained with both non-operative and operative methods of fracture treatment in their country. This nucleus later developed into a group called ASIF (Association for study of internal fixation) or A.O. (Arbeitsgemeinschaft fur osteosynthesefragen). The meeting was initiated by Maurice E. Muller who had spent some time with Davis and was impressed by his compression fixation of the fractures, the avoidance of external immobilization and early pain from active mobilization of the injured extremity. In addition, the treating of bone by socidure autogene (Primary bone healing) found by Danis was the very same thing. E.F. Cave (1958) has been looking for as an index of perfect alignment in the treatment of fractures when he said the more accurately a fracture aligned, the less demand there will be for the callus.
Rapid recovery of the injured limb, this is accomplished by:

- Anatomic reduction of the fracture fragments particularly involving joint surfaces.
- Stable fixation (Internal or external) designed to fulfill the local biomechanical demand.
- Preservation of blood supply to the bone fragments and soft tissues by means of atraumatic surgery.
- Early active pain free mobilization of muscle and joints adjacent to the fracture. In this way the development of joint diseases prevented.

Colonel Hampton, during World War II, utilized delayed primary internal fixation in 332 cases of compound fractures and reported maximum achievable results in 77.2% and failure in only 7.5%. He outlined the advantages of internal fixation as follows:

- Anatomical alignment.
- Repeated Manipulation avoided.
- Subsequent wound care facilitated.
- Early joint motion, muscle exercises facilitated.
- Management of concurrent injuries facilitated.

Zodik (1946) from his experience of managing 117 compound fractures of the femur concluded that early and adequate debridement was most vital factor in successful treatment of a compound fractures. They
treated 17 out of 117 cases by intramedullary nailing. They cautioned that use of early internal fixation in presence of open wound was accompanied by greater danger of complications.

Davis (1947) reported a series of 150 consecutive cases of compound fractures observed from 1936 to 1947. In all cases, treatment consisted of immediate debridement, metallic internal fixation, skin grafting and compression dressing. He attributed his better results, first to compression dressing (which excluded gases from deep tissue). Second to immediate coverage of surface defect with graft, third to immediate or delayed hair line reduction with metallic internal fixation whenever indicated.

Hampton (1955) emphasized that intramedullary nailing facilitated painless regular care of wound without jeopardizing the reduction.

Veliskakis (1959) reported 80 consecutive open fractures of tibial shaft treated by primary internal fixation and wound closure. Wound healing was complicated by deep infection in 10% and by skin loss of varying degree in 12.5%. Careful selection of patients on basis of associated soft tissue injuries was urged. The nature of soft tissue injury should be a deciding factor in choice of method of treatment. In the less severe injury (grade I) intramedullary nailing and wound closure might be safely employed. In severe injuries (grade III),
primary wound closure (with or without internal fixation) should be avoided. Moderately severe (grade II) fracture should be carefully assessed and treated by internal fixation and wound closure, only if primary wound healing was confidently expected.

Mukhopadhyaya (1970) showed the result of medullary nailing of open fractures of long bones in early cases i.e. within 6 hours, as well as late cases i.e. 12 to 14 hours and within 3 to 4 days. In early cases thorough toilet and primary closure with a suction drain were employed. In late cases, even in presence of infection a thorough toilet was done but the wounds were initially left open and covered with split skin grafts after 2-3 weeks, maintenance of alignment of the fragments, satisfactory union and absence of complications were in favour of this method.

In 1969, Brown and Urban reported the results of 63 open shaft fractures of the adult tibia. The cases were treated with early weight bearing. All fractures united with an average healing time of 19 weeks and all patients regained a functional lower extremity with good knee function.

Brown (1973) advocated 3 rules for fracture treatment i–
1. Leave the close fracture closed.
2. Leave the contaminated or infected open fractures open.
3. Early return of the injured limb to as near normal as possible.
A series of 30 cases of open fractures of tibia fibula treated by primary intramedullary nailing was reported by Harvey et al (1975). They preferred fibular nailing alone in the fracture lower third tibia fibula. In their series, they experienced infection only in one case that too superficial and without involvement of bone. They found that by using malleable light nail the disturbance produced at fracture site was minimum and in case of fibular nailing there was no disturbance at all at the tibial site.

After a retrospective and prospective analysis of 1025 open fractures during 1955-1973 Gustillo and Anderson (1976) stressed for adequate debridement and copious irrigation of wound with normal saline. Wound should not be closed if there is any doubt about the efficacy of debridement. Wound closure was advised in type I and II open fractures but not in type III open fractures. Antibiotics should be used pre and postoperatively.

Gustillo and Anderson suggested a classification for open fractures type I, II and III.

Type I

Small wounds of 1 cm or less caused by low velocity trauma, such as protrusion of a fragment of bone out from within or by a low velocity bullet passing in from without, with minimal damage to soft tissues, relatively clean wound.
Type II

Wounds extensive in length and width (≥1 cm) but with little or no avascular or devitalized soft tissues and relatively little foreign material.

Type III

Wounds of moderate or massive size with considerable devitalized soft tissues (including muscle, skin and neurovascular structure) or foreign material or both or traumatic amputations.

Farm injuries with soil contamination, irrespective of the size of the wound are included in type III.

In 1980, Campbell subclassified the third group.

Type IIIa: Wounds with extensive soft tissue laceration or flaps but with adequate soft tissue to cover fractured bone.

Type IIIb: Wounds with extensive soft tissue injury or those with periosteal stripping and bone exposure.

Type IIIc: Open fractures, associated with arterial injuries requiring repair.

An analytic study of 25 open fractures treated by primary internal fixation in Indian population was reported by Mohindra et al (1982). They observed that soft tissue healing was rapid after internal fixation of open fractures. Fracture could unite in presence of infection and infection...
could be controlled after removal of implant or sequestrum.

Marcus and Hansen (1987) treated 14 patients of multiple trauma with bilateral fracture of the tibia (28 tibial fractures) and of 28 tibial fractures, 16 were open fractures. They concluded that bilateral tibial fractures are usually the results of the high energy injuries associated with multiple trauma and resulting in high mortality rate. Early rigid stabilization of fracture can improve survival rate, facilitate early mobilization and soft tissue healing, minimise complications in multiple injury patients.

Michael Alms (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 by intramedullary nailing, the average time for absence from work was 13 weeks.

With all these obvious advantages of good fixation and early ambulation, internal fixation carries a definite risk of infection ranging from mild degree to involving whole of diaphysis.

According to Burwell (1971) there are many disadvantages of internal fixation: i) delayed wound healing, ii) sepsis, iii) loosening of implant leading to loss of rigid fixation, iv) delayed union and non-union, v) metal reactions and vi) fat embolism and venous thrombosis. Besides, in cases of compound fractures, the increased risk of infection makes it useless.
Thus, while treating a fracture of both bone leg, both conservative and internal fixation methods have their advantages and disadvantages and in cases of compound fractures both have their serious limitations. So at this stage in case of compound fractures of leg, treatment by applying an external fixator seems to eliminate most of the disadvantages of both methods and incorporates the advantages of both the methods.

External Fixation

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

The history of external fixation dates back to the year 1851 when Malgaigne and Levi employed claw-like external fixation devices for immobilization of patella for the first time.

In 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 the femur. This apparatus became known as Parkhill Bone Clamp. He was the first surgeon to recommend and employ rigid external fixation in the treatment of fractures of long bone.

In 1904, Codivilla 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 pin by Steinmann
(1907) various interpretations of its adoption, especially with regard to external fixation of the pins with plaster or mechanical devices were published by many workers.

Lambotte (1907) used an external fixation device similar to present designs. He used percutaneous half pins with a rigid external frame in case of femur and other long bones.

Freeman (1919) published an article advocating the use of external fixation in the treatment of fractures. He pointed out and emphasized the advantages of this method. But the method did not become popular due to through and through pinning.

In 1931, Stader working in the field of veterinary surgery was impressed with the inadequate methods then to use for treating the fractures of the shaft of the long bones of the dogs. Plaster encasements were not tolerated by the canine. He used two half pins units in each segment, connected by an adjustable metal bar. Till May 1942, he had treated over 1200 fractures in dogs, with uniformly good and superior results over the older methods of treatment.

Anderson (1934) devised a new apparatus i.e. a small fracture table 20 inch long with many adjustments, also called fracture Robot, to solve the problem of maintaining perfect reduction. After reduction of fracture, the pins transfixeding the upper and lower fragments were incorporated in the plaster cast so that reduction was not lost. He allowed the patient for crutch walking from the second day but weight bearing was not allowed for the first few weeks.
Lewis and Breidenboch (1937) treated first patient by Stader splint for fracture both bone leg at New York. After application of splint patient started bearing weight on injured limb in two weeks and walking without the aid of crutches or cane in three weeks. Between 1937 and 1942, a total of 20 patients were treated by this method with uniformly good results, except in 3 patients where infection around pins occurred which promptly subsided after removal of pins. The splint was kept in place until bony union occurred which varied from 8 to 16 weeks.

Mazet (1943) after his observations, gave a composite evaluation of Stader technique, and enlisted the advantages of this method as follows:

1. It presented the more perfect and accurate means of obtaining reduction.
2. It provided firm fixation.
3. It avoided distraction.
5. It was valuable particularly in cases of compound fractures, where dressing, skin grafting and bone grafting could be done without disturbing the fragments.

Naden, between 1942 and 1949 treated a total of 237 tibial shaft fractures with this method. He reported end results in 206 of them. In most of the cases having fractures in the middle shaft the proximal pin in the proximal fragment and distal pin in the distal one had been through and through. The other two were half pins. An
extra half pin was added to prevent side slipping. If the general condition of the patient was good, ambulation with the help of crutches was started the day after fixation. Full weight bearing was deferred till the evidence of clinical and radiological union. The average period for union of the simple fracture was 16.5 weeks and for compound fractures 22 to 34 weeks.

According to Johnson (1950), during World War II, the external fixation method was widely adopted, but by 1950's however, external fixation had fallen into disrepute because of high rate of complications reported to accompany the use of devices with poor adjustability and inadequate rigidity (Anderson, 1943; Davis, 1943; Naden, 1949 and Johnson, 1950). However, these complications could be attributed to the poor quality of external fixator itself. Although success was reported, pin tract infection and delayed and non-unions frequently occurred.

In 1950, Herman presented a retrospective study conducted by the committee on fractures and traumatic surgery of the American Academy of Orthopaedic Surgeons to evaluate the external fixation method of treatment. Out of 395, 186 surgeons found this method of treatment to have a definite place in fracture management, while 287 had used this method infrequently or had used but later discarded it, feeling that this treatment held no advantage over other methods. Advantages enlisted in this study were minimum surgical risk, shorter operative procedure, more secure
and adequate immobilization, early ambulation, shorter period of hospitalization, simplicity and speed of application, reduction of nursing care, early motion of joints, maintenance of bone length and absence of distraction. The disadvantages were soft tissue infection at pin sites, ring sequestra and osteomyelitis followed by non-union, pain, conversion of simple fractures into compound fractures and difficulty in obtaining and maintaining reduction. Pin track infection was the chief cause of discontinuing the use of external fixation.

In the post-war period many attempts were undertaken to develop better external fixation devices. In England, Charnley (1944) developed a simple frame for compression on certain fractures. Wagner in west Germany and Kawamura in Japan developed apparatus for limb lengthening. Russian workers such as (Ilizarov) and Americans including Croner developed systems in which the external frame possessed ring-like structures for augmented stability. The AO or ASIF group developed two systems with which they achieved notable success. The first device was of limited stability though of elegant simplicity, the second device was rigid but possessed a limited capacity for post-operative realignment.

One of the latest designs for external skeletal fixation is the four-poster double frame, developed by Raoul Hoffmann of Belgium in 1938. Hoffmann in his monologue written in 1951, described the use of single half pins
inserted into the medial subcutaneous area of the tibia, penetrating both the cortices, thus providing adequate stability and maintenance of reduction in fracture healing.

Vidal and Adrey (1968) in Montpellier, France examined and modified the Hoffman system. They largely developed the Hoffman device as it is currently employed. This system permits three plane correction of deformities and finer adjustments of limb length during and/or after application.

Burke et al (1977) reviewed 28 patients with a total of 28 fractures of long bones and six pelvic fractures treated with the Hoffmann external fixation apparatus. All of the extremity fractures were compound with varying degree of soft tissue injury including seven with neurovascular complications. In these patients a total about 54 secondary procedures consisting of debridement, skin grafting and bone grafting were performed with the apparatus in place. For tibial fractures the average period of immobilization had been 21 weeks. Pin tract infection was not a serious problem. They concluded that the device offered advantages which far out weighed the objections to its use in the management of compound fractures of long bones and infected non-unions.

Rezain (1977) of Sina Hospital, Tehran, Iran designed an external fixation device consisting of two external bars linked with bone by 4–6 threaded pins for rigid fixation of bone and used in 10 complicated tibial
fractures in which treatment with standard method had failed or had been considered. Full weight bearing started between 12 days to 3.5 months and all fractures united between 10 to 16 weeks.

Hierholzer et al (1978) of Germany after experimental and clinical experiences concluded that stabilization by using external fixation in problematic cases is clearly the method of choice because the risk of infection is far less than using the standard methods of plating and nailing. Correct application achieved rigid stability and allowed early mobilization ensuring alignment even in bone defects. This method also facilitated care of wounds and greatly reduced the risk of amputation in problematic cases.

Edwards et al (1979) of Maryland Orthopaedic Trauma Service reported the study of 44 compound tibial fractures in patients of multiple injuries. 73% of the cases were comminuted, segmental or had bone loss, 70% of total cases were grossly contaminated. 53% were associated with soft tissue loss. All cases had large skin wounds and displacement of fracture fragments. In all cases after initial debridement, double frame Hoffmann apparatus was applied and fracture reduced. Post-operatively the leg was suspended by hanging the apparatus from an over head beam. Once the wound was healed, the external fixator was removed and weight bearing cast was applied.

In this series, results indicated successful union, average time for early union was 4 months, with
complete healing (full weight bearing without cast) at 7.5 months. Good fragment alignment was routinely obtained. Considering all cases, external fixation was used for an average of 68 days. Bone grafting was required in 39% of cases, muscle flaps in 30% and skin grafts in 48%. 23% of the tibias developed osteomyelitis and 30% of cases had at least one pin tract infection, which cleared after the pin removal (only two of osteomyelitis tibia required eventual amputation).

Following successful use of Hoffmann external fixator in treatment of tibial fractures Edwards et al used the apparatus successfully to achieve early stabilization of femoral, humeral, forearm, elbow, knee and ankle injuries.

Fischer (1979) used external fixation in treatment of severe tibial fractures. He inserted most proximal and distal pin of each set first and then other pins parallel to these. He passed the pins directly through the lateral musculature of the leg.

Kuderna (1977), Saligson (1978) and Mears (1980) used it for compound comminuted fractures of femur and pelvic bones and found good results. Kanheim et al (1978) and Burney et al (1979) used it for treating simple and complicated fractures of humerus with good results.

Kenwright et al (1980) published the results of a prospective study of 103 patients having diaphyseal fractures, of the tibia over a period of 2.5 years. In 23 of
them with severe soft tissue injury, bone loss and infected pseudoarthroses, external skeletal fixators were applied and the rest were treated by functional cast methods. The external fixation technique comprised of 6 mm Schanz screws inserted through the medial surface of tibia and these were fixed to a clamp and bar system which maintained the control of the fracture in all instances and allowed early rehabilitation of the functions of joints and muscles.

In most of the patients the skin and soft tissue healed rapidly after external fixation. Cancellous bone grafting was done through postero-lateral approach at that stage. It was noted that when no bone grafting had been performed, considerably delay in union had occurred.

Four out of 102 screws required premature removal due to infection. No patient had screw hole fracture, nor was there any case of refracture, but in one case neurovascular complication took place. The fixator was removed after sound bony union.

Lawyer and Lubbers (1980) used four postero double frame external fixator developed by Hoffmann (1938) and modified by Vidal (1973). They experienced that properly applied external fixation can minimise and in most cases overcome the causes of delayed and non-union of fractures.

They concluded, “for those complex tibial fractures in which stabilization is essential (achievement of fracture stability is of primary importance in providing the proper milieu for wound healing) but in which internal
fixation cannot be done, properly applied external fixator provides an excellent alternative and should be the treatment of choice.

Aalto and Karaharju (1981) tested the mechanical stability of four external fixation devices which are in clinical use. In the tests different devices showed variable elasticity under stress. The stability of mounting with one tie bar was found to be approximately one third of that having mounting with two bars. They inferred that the external fixation devices in general could not be considered rigid. This elasticity was of no clinical importance in practice. The weak joints of the device were found to be the connecting joints between the bars and the transfixing pins (which gave way) and the transfixing pins (which bent under stress). They were of the opinion that rigid external fixation device could not be constructed and more over it did not even seem to be necessary.

Allerton and Miles (1981) of Groote Schuur Hospital, Cape Town, published his results of treatment of 38 acute open tibial fractures by external fixation employing methyl methacrylate bone cement (because they found transfixing pin and plaster cast method caused 20% soft tissue sepsis rate and 9% incidence.

They concluded - "External fixation allows free access to the wound in a limb unencumbered by a plaster cast, facilitating wound dressing and operative procedure
and also allows active physiotherapy. This is particularly important in patients with soft tissue damage, when the ankle joint must be kept mobile to prevent a fixed equinus deformity from developing. The wound sepsis rate in patients with open tibial fractures at Groote Schuur Hospital was reduced from 20% to 13% while during an 18 months period no case of bone sepsis has been observed. Finally, patient acceptance of external fixation has been exceptional and from the patients joint of view it appears to be the treatment of choice."

Kimmel (1982) treated 27 patients of severe fractures of tibial diaphysis by Hoffmann external fixator. All fractures were open, comminution was present in 66%, 50% were classified as grade III and 50% had other orthopaedic injuries. Ambulation was begun on average of 4.25 weeks after application. Patients beared weight about 10.75 weeks after the Hoffmann's device was applied. It remained in place for approximately 12 weeks on the average. The union averaged 39 weeks or about 9.75 months.

Gershuni and Halma (1983) reported a series of 33 cases of grade II and III open tibial fractures treated with local wound care followed by application of A.O. external fixator. Two transfixing Steinmann pins were usually used above and two below the fracture site. In 6 cases, one Steinmann pin and one anteroposterior Schanz half pin above and below the fracture were combined with a triangulated frame. Additionally, minimal internal fixation with leg screw was used in five cases.
Union was achieved in 83% of tibia in an average time of 9.9 months. Union occurred faster when the fixator was removed in less than 3.5 months but then the incidence of malunion tended to rise. Three patients required early amputation within one month of accident when vascularity was found clearly insufficient with gross muscular and neurological damage. 33% patients developed deep wound infection. Knee function was well preserved but ankle function was impaired in 50% cases. They concluded "The A.O. external fixator performed as a useful, simple, stable, light weight and versatile system in the care of grade II and III fractures. However, many problems intrinsic to the open tibia fracture remain."

Schmidt and Roraback (1983) treated 34 patients with fractures of tibial diaphyseal shaft by flexible anterior half frame external fixator. The average time to union in the frame was 12 weeks for a simple closed tibial fractures and 26 weeks for a complex open tibial fracture. Complication included displacement and loss of initial reduction in 21 cases, non-union in 6 cases (all healed by bone grafting) and infection in 4 cases. They concluded that for success most important factor is adequacy of initial reduction and second important factor is proper pin placement (to place the pins 5 cm on either side of the fracture).

Karlstrom and Olerud (1983) reported their experiences in a 12 years series of 111 severe open tibial
fractures (63 were grade III and 48 were grade II - in grade II group the fractures were all comminuted and unstable). They concluded “Stable external fixation of open tibial fractures promotes healing of skin and soft tissue damage, reduces the risk of infection and facilitates the treatment of patients with multiple injuries. In cases of very severe open tibial fractures this method seems to be the treatment of choice and can reduce the frequency of amputation.

They suggested “When fractures are treated by external fixation, adequate cancellous bone grafting should be done when cortical bone defects are present and when there are clinical and roentgenographic signs of delayed healing. Another reason for treating cortical bone defects by bone grafting is to reduce the risk of secondary fracture.”

Chan and Leung (1984) and Gustillo and Mendoza (1984) also used external fixator for grade III open tibial fractures and found it very useful in salvage of limbs, which would otherwise have been amputated.

Giovani (1984) studied the result of external fixation treatment of compound tibial fractures and found it a versatile method. He found average time of union 5.25 months.

Sarmiento (1984) reported the treatment of 134 severe open tibial fractures by Hoffmann's external fixation device. More than 70% were grade II and III
fractures and mostly comminuted. He found average healing time of 25.3 weeks (range 7-63 weeks).

Sahu and Sharma (1984) and Sahu and Dang (1985) in an experimental study on animals, compared it with the method of pins and plaster and found union to be rapid and more sound with external fixator.

Rooser and Hansoon (1985) of Sweden treated 5 patients with ipsilateral femoral and tibial shaft fractures. The Hoffmann's apparatus was used to stabilize the fractures of both the femur and tibia. All five patients were out of bed in a wheel chair or on crutches within 2 weeks and discharged from hospital within 6 weeks of injury. All fractures healed without secondary procedures. The average healing time for femur was 13.4 weeks and tibia 20 weeks. They concluded - "External fixation has offered an opportunity for early and stable fixation of fractures with a minimum of operative surgery, which is important in seriously ill patients. Furthermore, the stable fixation made the patients easy to nurse and permitted effective physiotherapy for their chests. The patients were easy to mobilize and active exercises could be started early."

Though most often used for treating fracture legs, the external fixation has been tried in the treatment of other long bones as well as pelvic fractures.
Leland Mayer et al (1985) treated 51 severe tibial shaft fractures between November, 1979 and January, 1983 by multiple intramedullary enders nails. 41 fractures united in less than 4 months. Two tibiae failed to unite and in two there was angulation of 7°. They concluded that ender nailing was of value both for acute management of complicated high energy fractures of tibial shaft with extensive soft tissue damage and as a salvage procedure.

Robert J Candle et al (1987) treated 62 type III open fractures of tibial shaft. Out of which 11 were type IIIA, 42 were type IIIB and 9 were of type IIIC injuries. They treated fractures by external fixation, cast immobilization and intramedullary nailing and concluded that early aggressive reconstruction of soft tissues to cover exposed bone reduces risk of infection, non union and subsequent amputation significantly.

John L Holbrook et al (1989) conducted a randomised, prospective study comparing ender nailing with external fixation for open fractures of sixty three tibiae and proved ender nailing to be at least as effective as external fixation with respect to seven parameters – time of union, alignment, total number of operations, range of movement at knee and ankle, pain, presence of infection and complication. They concluded that ender nails are a safe alternative to external fixation in Grade I and II open fractures.
Piotr A Blachut et al (1990) treated 41 open fractures of tibial shaft with debridement and provisional external fixation between 1983 and 1989, followed by delayed soft tissue closure and subsequent intramedullary nailing with reaming. The average duration of external fixation was 17 days and average time between removal of fixator and intramedullary nailing was 9 days.

Of 39 patients having adequate follow up, 2 had a deep infection, 2 non unions and 1 delayed union. Satisfactory results were obtained in 37(95%) patients.

Cramer and Thomas (1992) reviewed the results of treatment of 40 open diaphyseal fractures of lower extremity in thirty five children between 3 and 16 years of age. Modalities used were external fixation and cast immobilization after debridement. 22 fractures healed primarily. There were 3 amputations, 12 delayed unions and 3 non unions. 10 of the 40 fractures were associated with infection but osteomyelitis developed in only one patient. No patient had growth arrest.

Tornetta and Bergmen et al (1994) reported early results of a randomised, prospective study comparing external fixation with non reamed locked nails in grade III-B open tibial fractures of 29 patients. 15 were treated by nails and 14 by external fixation. Both groups had the same initial management, soft tissue
procedures and early bone grafting. All 29 fractures healed within 9 months but the nail group had slightly better results and better motion and less final angulation. Complication included one deep infection and two pin track infection in external fixator group and one deep infection and one vascular problem in nailed group. They considered locked non reamed nailing as the treatment of choice for group III-B open tibial fractures.