REVIEW OF LITERATURE
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The primitive man, nay, even the lower animals instinctively found empirical treatments for all their ills and injuries. As the mind of man matured, the archaic medicine became a combination of his religious, magical and empirical views and practices. Thus in the ancient civilization extending from the Indus to the Nile, wherein religion was an important part of the daily life, the disease was considered as a punishment from the heavenly bodies, the spirits, the demons and the witches.

It is without doubt that thousand years before the Christian era, there was a civilization in India. The excavations of Mohan-Jo-Daro in Sindh indicate that during this period there existed a fully developed city with people living in houses with bathrooms having elaborate drainage system. Aryan invaders conquered this civilization and settled down in the Indo-Gangetic Plain. The theory and practice of ancient Indian or Aryan medicine took shape during a period which could be placed somewhere between 3,000 and 2,000 B.C. The documentary knowledge about this Vedic period is derived from Vedas. The fourth, the Atharva Veda, deals with the science of medicine. This science had been called Ayurveda, (Ayuh-life, Veda-to know) - the "Knowledge of life". The Ayurveda flourished and was at the zenith of its glory from 2,000 B.C to 1,000 A.D. It is unfortunate that the Ayurveda is no more available in its original form, but most of its contents are revealed to us by.

The Samhitas of Charaka and Sushruta, which were originally written about 1,000 B.C. The Sushruta Samhita is acknowledged as "one of the greatest of its kind in Sanskrit literature - especially important from the surgical point of view".

The Atharva Veda recounts many of the surgical miracles of the Rig Vedic pantheon, but it also give some idea regarding the practice of the orthopaedic surgery in those times. There is a clear reference to the surgical skill of the Atharvans in mending a broken bone, in a hymns addressed to an herb thus:

Thou art the healer, making whole,
the healer of broken bone
Make thou this whole, Arundhati!
Whatever bone of thine within thy
body hath been wrenched or cracked,
May Dhatar set it properly and
join together limb by limb
With marrow be the marrow joined,
thy limb united with the limb,
'Let what hath fallen of thy flesh,
and the bone also grow again
Let marrow close with marrow,
let skin grow united with the skin
Let blood and bone grow strong in thee,
METHODS OF REDUCTION & MANAGEMENT
OF FRACTURE AND DISLOCATIONS

REDUCTION OF DISLOCATION

REDUCTION OF DISLOCATION

KAPATA SAYANA

FRACTURE OF THE BONES OF THE LEG

FRACTURE OF THE THIGH BONE

DOUBLE FRACTURE OF THE THIGH BONE AND BONES OF THE LEG

FRATURE OF THE SPINAL COLUMN

FRATURE OF THE BONES OF THE THORAX

FRACTURE AND DISLOCATION OF THE CLAVICLE

PLATE-2
flesh grow together with the flesh
Join thou together hair with hair,
join thou together skin with skin
Let blood and bone grow strong in thee
Unite the broken, o Plant
A rise, advance, speed forth
the car hath goodly fellies naves and wheels
Stand-up erect upon thy feet
If he be torn and shattered
having fallen, into a fit, or
a cast stone have struck him,
Let the skilled leech join limb with limb,
as twere the portions of a car

The orthopaedic treatment, which was based upon the rich experience of the surgeons, was rational, and at times ingenious. The fractures were correctly diagnosed, the dislocations were elaborately classified, and treated among other things, with traction by means of a pulley (Chakra); the splinters (shalya) lost or deep seated in the organism were dexterously handled.

Sushruta has described 12 types of fracture as "Kanda-Bhagna" and described six types of fracture as "Sandhimukta," of bones and joints, which are produced by a variety of causes, such as, by fall, pressure, blow, violent jerking or by bites of ferocious animals. In the treatment of the fractures of the lower extremities, mention is made of the Kapata-Shayan (door-bed) or a fracture bed consisting of a plank of wood resembling the panel of a door. The patient is to lie down on it. The board has five or more pegs to be fixed in different positions (depending upon the site of the fracture) and the fractured limb is tied to these pegs to immobilize it, with two pegs on each side of the joint and one against the plantar surface of the foot. Immobilization of fracture was also affected by bandages (Bandha) or by means of bark splints or bamboo strips. Charaka has mentioned a medicated bandage "Ravalika" which was to be applied under the splints and tied firmly after setting the fracture.

Apart from these references of ancient Indian Medicine, no clear concept of fracture treatment is available till the middle of 18th century. Hippocrates (480 - 377 B.C.) the Ascleplad of cos, was the greatest physician of the golden age of Greece, in writing almost 2400 years ago, described a method of external skeletal fixation that served his need for a way to immobilize a fracture of the tibia, while at the same time permitting an associated wound or soft-tissue injury to be inspected and treated. There were attempts to produce sophisticated splints as shown in Sanigny's instruments catalogue of 1798. Crammer wire was popular too, first illustration of such a wire mesh is found in 1845.

Amesbury, who practiced in the first half of 19th 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).
SEVERAL OLD AND NEW EXTERNAL FIXATORS

EXTERNAL SKELETAL

FIXATION DEVICE OF HIPPOCRATES

(A) MALGAIGNE'S POINT (1843)

(B) MALGAIGNE'S CLAW (1843)

PARKHILL'S BONE CLAMP (1897)

LAMBOTTE FIXATOR (1902)

HOFFMANN'S EXTERNAL FIXATOR (1938)

CHALIER (1917)

JOLY (1933)

CUENDET (1933)

PLATE – 3
SEVERAL OLD AND NEW EXTERNAL FIXATORS

ANDERSON (1933)

GOOSSENS (1939)

JUDET (1956)

CHARNLEY (1948)

VIDAL-ADREY (1970)

Rezaian Fixator

SHEARER EXTERNAL FIXATOR

PLATE-4
Scutin (Monro, 1935) had allowed the patient to mobilize in his cast of starch impregnated bandages. Turkish Empire (1790) reported that the setting of bones was practised by enclosing the fractured bones in case of plaster of paris. Matthysen (1852) a Dutch man was the first to device plaster of paris bandage by rubbing the powder into coarse cotton material on a table. He popularized the use of Plaster of Paris bandages and recommended that the fractured limbs were to be immobilized with one joint proximal and one distal till complete union occurred.

External fixation is a method of immobilization that was percutaneous pins placed in bone and linked with external connectors. The concept of external fixation appears in works of Malgaigne from the mid-19th century. Since Malgaigne’s invention, many other external fixation systems have been introduced, and external fixation is currently having a status of a standard method for treating fractures.

Four phases can be recognised in the history of external skeletal fixation (1) the concept of external fixation, (2) the practical realization of external fixation, (3) Bio-mechanical analysis and (4) improvement in the external fixators.

The concept of external fixation

The external fixation method was, as early as described by Jean-Francois Malgaigne in 1840, who used a simple metallic "point" which was a spike introduced into bone and held by straps to prevent displacement of fractures of the tibia. In 1843 he devised an ingenious mechanism consisting of a "clamp" that approximated four transcutaneous metal prongs for reduction and maintenance of patellar fractures. He described two problems inherent in fixation, "First, to let the patient have access to the screw. Second, to require a substantial force to tighten and loosen the screw, a force which caused the whole appliance to move and was very painful for patient."

In 1850 Rigaud of Strasbourg treated a fracture of the olecranon using two screws brought together with a simple string. In 1870 Beranberger-Ferand improved Rigaud's technique by joining the screws with a wooden bar, he also described in his "Traite de l'immobilization directe des fragments osseux dans les fractures" an external fixator for mandibular fractures.

In 1893 Keetley, noting the frequency of malunion in the femur, recommended that rigid pins be inserted percutaneously and held in a special external fixation device.

In 1894, Clayton Parkhill and Albin Lambotte invented the first readily available external fixators. Parkhill, an American surgeon from Denver, designed a "bone clamp". He fixed some difficult fractures of femur, inserted screws from cortex to cortex and then connected them with an external clamp, this apparatus became known as "Parkhill bone clamp."

In 1902 Lamotte, A of Antwerp, Belgium, the father of systemic fracture surgery, designed his external fixator independently.

Lambotte in 1912 and Humphry in 1917 were probably the first to advocate the use of threaded pins, but they used only one above and one below the fracture site.

In 1907, Steinmann, F. advented the Steinmann pins and these were then utilized in regard to
external fixation with plaster or mechanical devices. During this period Bohlar devised a simple reduction frame and screw traction apparatus in conjunction with pins or wires.

Lamare described the use of half pins placed at an angle to each other through the outer and inner cortices only bridging them in units by means of metal bars thus opening a new approach to external fixation. During the period of trans-fixation of fractures by various methods, efforts were made to eliminate the use of plaster.

Crile, D.W. in 1919 advocated an external fixator particularly adopted for fractures of the femur associated with war wounds, but this technique gained very little popularity.

In 1930, Riedel, G attempted to use half-pins connected to an external clamp to maintain the position in Schanz type osteotomy of the hip.

In 1931, Bosworth described a device for tibial lengthening, and Pitkin and Blackfield in 1931 were the first to advocate pins inserted through both cortices and attached to two external fixation clamps.

In 1932, Schanz described the use of half nails and screws as a means of skeletal control and Riedel suggested the use of an external plate bridging two or more screws or nails thus permitting firmer fixation.

In 1934, Roger Anderson devised an apparatus, a fracture table 20 inch long with many adjustments, also called as fracture Robot. After reduction of fracture he used to incorporate the transfixing pins in plaster cast. He allowed the patient for crutch walking on second day, but body weight bearing was not allowed for first few weeks. In compound fracture with extensive soft tissue injury the leg was left completely exposed in the splints for many weeks as necessary, while the wound and fracture were receiving simultaneous repair.

Roger Anderson, Anderson and Burgess, Anderson and Finlayson, Anderson et al and Anderson and O'Neill of Seattle, during the period from 1933 to 1945, presented a series of papers concerning the use of half pin and whole-pin long bones, arthrodesis and leg-lengthening procedures.

In 1937, Otto Stader, a veterinarian, introduced pin fixation with an external splint for the treatment of fracture in small animals. Some surgeons applied Stader's methods to human patients, with varying results.

From 1930 to 1950 this method fell into disrepute in North America due to the lack of rigid fixation by the pins and external frames and frequent pin tract infections although there were some published reports of good results.

From 1938 to 1954, Raoul Hoffmann of Switzerland presented a series of articles describing his method of external fixation, and numerous authors in Europe and Scandinavia subsequently reported excellent results in their series using this technique.

These reports brought about an upsurge in the popularity of external fixators, prompting the Committee on Fractures and Traumatic Surgery of the American Academy of Orthopaedic Surgeons to initiate a survey to evaluate the efficiency and practicality of this method of treatment so that its place in the methods of fracture management might be determined (1950). Through a series of extensive
questionnaires, the committee concluded that, while it may have a definite place in orthopaedic surgery, external fixation should be used only under the supervision of a surgeon who had treated at least 200 patients by this method. Use of the method by physicians without adequate training was not advocated.

In 1948 Charnley popularized his compression device to facilitate arthrodesis of joints and this technique rapidly grew in popularity.

In 1952, the first AO external fixator was designed by M.E. Muller, by which stable fixations could be achieved only if one applied axial compression.

In 1968 and 1974, Anderson and associates reported the use of transfixing pins incorporated into a plaster cast for the successful management of large series of tibial shaft fractures, as did Sladek and Kopta.

From 1978 to 1979 Vidal and Vidal et al modified the original Hoffmann device from a single half-pin unit to a quadrilateral bicortical frame, greatly increasing its rigidity. These investigators greatly expanded the indications for and usage of external fixation.

In 1969 Vincent et al presented a five year follow-up 75 human lower third tibial shaft fractures treated by percutaneous semi-rigid fixation. They inserted four pins, one each through Calcaneum, tibial tubercle, and above and below the fracture site. Pins were incorporated in a short leg plaster cast. In these patients, immediate weight bearing was initiated. All the fractures united with an average of ten and half weeks without any considerable complication.

Jorgensen, Olerud, Karlstrom and Olerud and others further documented the usefulness of the technique in a variety of compound and/or comminuted fractures and non-unions during the following several years.

Day frame was then designed in 1975 to facilitate the management of unstable compound fractures of the tibia and arthrodesis of ankle and knee. It utilizes Steinmann or Denham pins usually two or three above and below the fracture. The pins are held in a clamp on each side, locked by hexagonal nuts. The clamps are interconnected by bars of 10mm diameter held onto the clamps by universal joints of unique design. This frame was used for mainly tibial fractures with severe soft tissue damage and also in femur, pelvis and humerus.

In 1976 Aron used dental methyImethacrylate to fix the transfixing pins with the vertical side bars in cases of old infected fractures or previously infected non-union of long bones.

In 1979, Oxford external fixation system was developed by Oxford orthopaedic Engineering Centre. It is for single sided application, is light in weight and un-obstructive in nature. It provides rigidity in fracture fixation whilst allowing adjustments in all planes during surgical operations.

In 1981, A. J. Edge and R.A. Denham used Portsmouth external fixation device, three Steinmann pins were passed above and three below the fracture site and are fastened with acrylic cement to mobile carriages on the external bar. The position of the carriages being governed by the locking nuts.
2. Practical realization of external fixation

Clayton Parkhill, an American surgeon from Denver, designed a "bone clamp" in 1894. In 1897 and 1898 he reported a total of 14 patients treated successfully and declared with enthusiasm, "We claim for this instrument first, that it may be easily and accurately adjusted, and prevents both longitudinal and lateral movements between the fragments, "second, that nothing is left in the tissues which might reduce their vitality and lead to pain or infection, "third, that no secondary operation is necessary, "fourth, that no method has ever before given 100 percent of cures."

In 1902 Lambotte designed his external fixator. According to Lambotte, "The advantages of the fixator are numerous and very real. The apparatus can be easily and rapidly installed, it has a great rigidity. Open wounds can be easily dressed. It has the advantage over all the other methods of fixation that it can be completely removed without difficulty. Finally, the state of consolidation can be controlled before its removal. During the course of treatment, one can mobilize the limb actively and passively. These characteristics are a considerable advantage for severe leg fractures. In numerous cases, one could avoid, thanks to the fixator, amputation that seemed inevitable.

Lewis and Breidenboch in 1942, had the opportunity of visualizing the Stader splint applied to a police dog for fracture shaft femur. They were much impressed by the ease of its application, the prompt and accurate reduction obtained and the simplicity of the instrument. In October 1937 he treated the first patient by Anderson's fracture robot in the fourth division of Bellevue Hospital, New York. The patient was able to bear weight on injured limb in two weeks and walk without the aid of crutches in three weeks. Between 1937 and 1942 20 patients were treated by this method with uniformly good results, except in three 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 eight to 16 weeks.

Anatomic and Haynes splints were also used by Bradford and Wilson in 1942 in 61 cases at American Hospital in Britain and they concluded the following advantages of mechanical pin fixation in war surgery:

1. Early ambulation
2. Quick evacuation
3. Maintenance length and position in cases where there was loss of bone substance
4. Easy dressing and access to the wound without disturbing the fracture especially in cases of infected fractures which tend to be displaced

Shaar and Kreuz used Stader splint in 157 cases of various types of fractures in 1943. They analysed 84 cases of simple fractures and 21 compound fractures of tibia and fibula. No pin track infection was reported. None of the cases passed into non-union knee and ankle movement restored normally and no physical therapy was required. They advocated stades splint as an ideal device for treatment of compound and comminuted fractures of tibia. Naden also treated 237 cases of tibial shaft fractures by this method during 1942 and 1949. 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 the next day of fixation. Full weight bearing was deferred till the evidence of clinical and radiological union. In his series average union time for simple fracture was 16 weeks and for compound fractures 22 to 34 weeks. 50 percent of the patients had minor local irritation around the pin track. In one case pin clamp broken after a month leading to displacement of fractured fragment. One patient had sloughing of peroneal group of muscles with lateral popliteal nerve involvement which improved with time. Two cases of simple fracture and four cases of compound comminuted fracture with bone loss passed into non-union, which were later treated by bone grafting. Four patients showed small ring sequestrum around the pinsites. He also reported two cases of lateral bowing, two of posterior bowing and five of shortening and 25 developed arthritis of the ankle and 27 had arthritis of knee either alone or combined with restriction of movements.

A retrospective study was carried out by the American Academy of Orthopaedics to evaluate the external fixation method of treatment. This study was presented by Herman in 1950. Only 108 surgeons out of 395 advocated this method to have definite place in fracture management. 287 had used this method sparingly and later discarded it feeling that this method held no advantage over other methods. Advantages included minimal surgical risk, shorter operative procedure, more secure and adequate immobilization, early ambulation and shorter period of hospitalisation, simplicity and speed of application, reduction of nursing care, early motion of joints, maintenance of bone length and absence of distraction.

Disadvantages included soft tissue infection at pin sites, ring sequestra and osteomyelitis followed by non-union, mechanical difficulty, pain and conversion of simple fractures into compound fractures.

Karlstrom from 1970 to 1973, treated 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. in 1977 reviewed a series of 28 patients 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 out-weighed the objections to its use in the management of compound fractures of long bones and infected non-unions.

Cumming, W.J. in 1979 reported improved results with functional cast bracing and external fixation devices specially in high velocity injuries to shaft of tibia and fibula. He was of the opinion that most of the external fixation devices in use were unnecessarily complex expensive and had the disadvantages of loosening. He recommended the use of dental acrylic cement in preference to simple longitudinal bars to hold threaded transfixing pins.

In 1979 Edward reported open tibial fracture in patients of multiple trauma. 73 percent of cases had bone loss or major comminution; 55 percent 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 by an overhead beam. Once the wound was healed, the external fixation was removed and weight bearing cast was applied.

A review of 1421 cases of tibial fractures treated by external fixation between 1960-1977 was presented by Burrey in 1979. His cases included simple fracture on one hand and open comminuted fractures and infected pseudoarthrosis on the other. Simple fixation i.e. half frame, was used in majority of cases. Very comminuted fractures required simple frame and triangular fixation.

Kamhin et al. reported eight fractures of humoral shaft in which external fixator was used. They inserted four Schanz screws through a drill guide into the humerus, two above and two below the fracture engaging both cortices. They were of the belief that external skeletal fixation has a place in the treatment of fractures of the shaft of humerus when faced with:

(a) Cumminuted fractures,
(b) Bone defect,
(c) Much skin loss in an open fracture,
(d) An aged patient in which immobilization is undesirable,
(e) An associated lesion in the same limb when early movement is needed.

Lawyer and Lubber (1980), using Hoffmann Apparatus in 34 complex tibial fractures otherwise considered to have a poor prognosis with other forms of treatment found complications to be minimum with time of union being 5-8 months for all depending directly on accuracy of reduction, time being as short as 5-1 months in 25 cases where anatomical reduction was possible with compression. In the rest not fulfilling the two conditions time to unite was 8-2 months. No shortening or significant angulation of fractures did occur, deep wound infection being prevented by serial debridement and stabilisation.

In 1980, Ken Wright et al., 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 pseudoarthrosis, external 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 the 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, considerable delay in union had occurred. Four out of 102 screws required premature removal due to infection. No patient had screw hole fracture. In one case neurovascular complication took place. The fixator was removed after sound bony union.

Pal Benum and Svein Svenningson (1981) presented a study of 45 tibial fractures treated by Hoffmann external fixation device from 1974-1979. Thirty-three percent of them were complicated. Twenty-five fractures were treated by original Hoffmann device and 20 by the modified device of Vidal-Adrey with a double frame. The average healing time was 28 weeks. There was one with deep infection and two patients were re-operated for delayed union. No patient developed pseudoarthrosis or
serious pin track infection. They also concluded that the double frame increased the rigidity of fixation considerably.

Bryd Steve, M. et al (1981) reported a series in which they treated 20 type III tibial fractures. They employed a combined orthopaedic and plastic surgical scheme based on the tenets of early debridement, "second-look" operations, muscle or muscles skin flap cover within five days of injury, external pin fixation, ambulation within three weeks of injury. All fractures united in mean time of four months. The mean hospitalization was 4.2 weeks. There was no chronic infection, osteomyelitis, non-union, shortening or tissue break down.

Fred Behrens et al (1983) published a prospective survey of severe open tibial fractures. Type II and III were admitted to St Paul- Ramsey Medical Centre during 1978 to 1980. All fractures were immobilized initially by a unilateral frame that contained components of the AO/ASIF tubular device. The incidence of serious complications with relatively rigid one or two plane unilateral fixator frames was considerably lower than with internal fixation by plates and screws. Unilateral configurations that contain rigid components provide better wound access than bilateral frames and interfere less with knee and ankle movements. They allow unencumbered partial and even full weight-bearing. This increases comfort of fracture healing. No standard formula exists, however, for the application of an optimal unilateral frame. The clinical and mechanical demands of each patient and injury must be considered individually.

In 1983 Gershuni and Halma reported their series of severe open tibial fractures treated by AO external fixator. They recommended it as a useful, simple, stable, light weight and versatile system in the care of grade IIIC & IIIb compound fractures.

Velazco and Nahai in 1983 used Hoffmann external fixator for soft tissue reconstruction of leg associated with severe compound fractures. It allowed them bony stabilization and did not preclude the subsequent soft tissue reconstruction or bone grafting.

Goldstrom et al in 1984 used external fixator for 39 fractures with segmental bone loss or limb length discrepancy. The results in achieving length were very encouraging. He achieved union in almost 80 percent of patients, with 95 percent or better anatomic length.

Gustilo et al in 1984 and Chan et al (1984) also used external fixation for grade III open tibial fractures and found it very useful in salvage of limbs, which would otherwise have been amputated.

In 1984, Andrianne et al published a series of prospective study of 53 patients with 84 fractured bones (ulna, radius or both) treated by Hoffmann External fixation during 1977 to 1983. The radial nerve is the main anatomical obstacle to be considered. Whenever possible, close methods of reduction are used. The rate of pseudarthrosis (6 percent of the treated bones) is comparable or even lower than the greatly varying figures published in the literature. External fixation seems capable of restoring and maintaining the precise anatomical configuration of the forearm bones.

overall goal of a painless wrist with excellent motion, good strength, and satisfactory cosmeris appears to have been achieved by this method of management

In 1984, Ricciardi and Diquigiovanni reported a series of study "The external fixation treatment of Distal Articular Fractures of the Radius." That series of 48 wrist fractures treated with external fixation was presented at the Tenth International Conference on Hoffmann External Fixation, Brussels, Belgium, September 1983 It is stressed that the external fixator allows nursing care and treatment of soft tissue lesions without compromising reduction of the fractures. They suggest application of external fixation to wrist fracture in all patients with comminuted fractures of soft-tissue problems

Sahu and Dang (1984) 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

Cannon et al (1985) reported 30 patients managed with the use of a simple means of external fixation. Ten of these patients had multiple injuries, between 1976 to 1981. In 18 the fractures were open. Five cases had loss of bone length and infected wounds when first seen and were treated with the aid of micro-vascular surgical procedures. Eight cases required skin grafting. One case required a vein graft of the popliteal artery. The method described is simple to use. It requires little previous experience and is cost effective. They have recommended it's use in the initial treatment of the grade II & III open fractures. It may also be used on closed unstable fractures, and will maintain limb length in severe injury with loss of the bone-substance while further treatment is considered or performed.

Vaughan et al (1985) used Roger Anderson external fixator in the treatment of unstable fractures of the distal radius in 52 patients. They found that 46 patients had good or excellent results and six were fair.

Gottschalk et al (1985) quoted that severely comminuted and open fractures of the femoral shaft are usually unsuitable for internal fixation. Between July 1981 and March 1983 they treated seven patients using ASIF tubular external fixator system or the Wanger apparatus. All the fractures united within eight months in a good position without shortening and did not require additional operation. The use of the external fixator in these patients reduced their time in the hospital and facilitated their post-operative rehabilitation by allowing uncomplicated healing of a complicated fracture.

Rooser et al (1985) reported five patients with ipsilateral femoral and tibial shaft fractures using Hoffmann apparatus for stabilization. The patients walked early and there were no disturbances of fracture healing. It is suggested that in patients with ipsilateral fractures of the femur and tibia, external fixation is indicated for the tibia and the fracture of the femoral shaft should be stabilized by closed medullary nailing. If the patient is critically ill or if there is gross comminution of femur external fixation is indicated for this fracture as well.

Slatis and Paavolainen (1985) presented a paper "External fixation of infected non-union of the femur", a one-stage method of treating infected non-union of a fracture of the femoral shaft. The method involves excision of dead and infected tissue, resection of bone ends, cancellous bone grafting and fixation with an external frame. Four out of five cases were successful within seven months.
Shlomo Porat et al (1986) reported seven cases of femoral fractures, in head-injured children with spasticity and/or decerebrate posturing and seizures, who were treated with external fixation using Day external fixators or Mini-Wagner leg lengthening devices. The fracture healed with good alignment, maintenance of length and without infection. The technique is recommended both for its simplicity and lack of complication relative to other management approaches.

D.G. Papageorgiou (1986) reported 11 open comminuted severe fractures of the distal third of the forearm treated by percutaneous pin fixation. All 11 patients were judged to have excellent or good results. The lack of serious complication is attributed to the use of the external fixation device, which provides rigid fixation and allows wound redressings and early range of motion exercise without risking loss of alignment.

Evans et al (1988) reported performance of a new external fixator, was assessed in 50 cases of various types of fractures of the tibia. The fixator comprises an adjustable single outrigger bearing offset pins which offers considerable versatility in its use. The angle at which the pins are offset gives the device considerable torsional and angular stability, but its compressive strength is low, allowing axial loading of the fracture during weight-bearing. The incidence of complications such as non-union, malunion, and pin-track infection was low. The time to bony union was shorter in cases in which the fixator was applied without exposure of the fracture compared with those in which the fracture was reduced under direct vision. The time to bony union was also slightly shorter in cases where external fixation was the primary form of treatment, compared with those receiving preliminary or calus traction.

Murphy et al (1988) reported one hundred complex femur fractures, treated with the Grosse-Kempf inter-locking nail and 35 were treated with the Wagner External Fixation Device. Retrospectively, they analyzed the results in the two groups to determine specific indications for the future use of these nails. The Grosse-Kempfnail, although a technically demanding procedure, achieved excellent overall end result in comminuted closed fractures and in type I & II, and some type III open fractures after appropriate wound care, they found that the Wagner apparatus was a simple, easy device for obtaining initial fracture stabilization in contaminated type III B and type III C open fractures. It does however require substantial post-operative care, four cases required secondary intra-medullary nailing. We found a high infection rate with secondary reamed nailing after initial stabilization with external fixator.

M. Ali Noor (1988) reported use of simple and inexpensive external fixator. It is constructed of galvanized iron pipe and mild steel bolts and nuts. It can easily be manufactured in a hospital workshop with a minimum of tools.

Rommens et al (1988) reported a series of 95 patients with fresh fracture of the shaft of tibia, treated primarily with a Vidal Adrey transfixation frame, were studied retrospectively. Only 20 fractures attained clinical and radiological consolidation within four months after injury. Pseudarthrosis was seen in 12 patients. The external fixator was attached for an average time of 25 weeks. Pin loosening was seen in seven patients, minor of the wrist and leading to much better anatomical result, these factors did not permit any improvement in the wrists' early functional recovery. One year following injury the grip strength...
of the fixator treated group was significantly superior to that of the plaster treated patients.

Hsin-Nung Shih et al (1989) reported a series of 22 children with remoral shaft fractures, between the age of 10 and 14 years, who were treated with the Hoffmann external fixation apparatus from 1980 - 1985. This simple method requires less surgical exposure and allows earlier ambulation and easy nursing care. In addition, it makes patients comfortable in multiple trauma conditions. The average time to union and removal of fixators was 72 days. There was no deep wound infection, non-unions or rotationary deformities. All patients regained the range of motion of knee joints in three months without significant leg length discrepancy of radiological evidence of growth disturbance. The device may serve as an alternative method for femoral shaft fractures in prepuberty, especially in area of tropical climate.

Linnox et al (1989) organized, a study to evaluate the use of a one plane external fixation device to treat comminuted fractures of the distal radius. Clinical and roentgenographic data were obtained in 20 patients with follow-up ranging from 12 to 20 months. The results were graded: 14 excellent, four good, two fair and none poor. The use of the Clyburn External Fixation Device with supplemental radial Styloid Kirschner wire fixation achieved acceptable results in the treatment of comminuted distal radius fractures and proved to be easily applied.

Rommens et al (1989) reported 119 fresh and complex fractures of the lower leg treated with a Hoffmann Vidal-Adrey external fixator during 1978-1986. Ninety five fractures could be followed until bony consolidation. In 12 fractures a pseudarthrosis developed, and a deep infection in four. The external fixation device was attached for an average time of 25 weeks. Pin loosening was seen in seven patients, minor pin tract infection in 9 and major pin tract infection in 3 patients. Fourteen fractures needed a secondary internal fixation, in 17 cancellous autogenous bone grafting without internal fixation was carried out. They further stress that after healing of the soft tissue, the tibial fracture can be regarded as a closed one and other therapeutic procedures to accelerate bony consolidation should be taken into account. The alteration from external to internal fixation makes an early removal of the external fixator possible and prevents in this way the intrinsic problems combined with this fixation type such as delayed union, non-union, pin-loosening or pin tract infection.

Bassey, L.O. 1989 quoted a consideration to the relatively high complication rate of internal fixation methods in the management of open fracture, 16-36 percent the use of 'fixateur externe' or Hoffmann's apparatus is widely accepted as the best method of management. They did not have this valuable apparatus in their hospital due to the socio-economic constraints typical of developing countries. They found a valuable improvisation in the use of Bohler's transfraction methods and even to the extent of achieving osteotaxis and ambulation. The management method is described with our positive experience of its use in 28 cases of open fractures and other bone and joint afflictions. The advantages and disadvantages of the method are discussed. The method is recommended as a valuable substitute for the 'fixateur externe'.

Jorge Alonso et al in April 1989 reported the study of 24 femoral fractures managed by either an A or a Wagner external fixator during 1983-1986. Indication included open fractures with soft tissue...
injury in 13 patients, in comminuted shaft-fractures in six patients external fixation was a temporary method (Group I), while in ten patients it was the definitive method of stabilization (Group II). Twenty one patients achieved solid union, two developed a delayed union, and one had a non-union. Three patients developed pin-tract infections, and one developed osteomyelitis after intramedullary fixation in group I. Two patients developed shortening (2.1 cm and 3.2 cm) in group II. Loss of motion occurred in 11 patients, averaging 56 degrees. It has been suggested that external fixation be considered in the following types of femoral fractures, open fracture for aggressive management of soft tissue injury, closed fractures in severely traumatized, burn or head injury patients, fracture about the knee resulting in floating knees, and infected femoral non-union and pseudarthrosis.

Allan W. Bach and Sigvard T. Hansen, J.R. in 1989 published a prospective study of 59 patients with Grade II or III open tibial shaft fractures comparing internal and external fixation. Bony stabilization was with plating by AO principles or with external fixation with the one-half pin technique, prospectively randomized. In twelve cases, minimal internal fixation of the tibia and external fixation were combined. Definitive wound closure was delayed in all cases. Three free-flap transfers and two gastrocnemius myoplasties were done, vascular injury necessitated three early limb amputations. Fifty-six patients were followed for at least one year. Five plate fixations (19%) were complicated by severe osteomyelitis. In one case (3%) treated with external fixation severe osteomyelitis occurred. Three pin-tract infections occurred. In two patients, a 10 degree antero-posterior angulation occurred after external fixation removal. One patient healed with a 25 degree external rotation deformity. At final follow-up evaluation, all tibial shaft fractures had healed. Knee and ankle ranges of motion were affected by ipsilateral femoral shaft fracture, knee injury, or ankle and foot trauma but not by ipsilateral femoral shaft fracture, knee injury, or ankle and foot trauma but not by the type of fixation. Both methods yielded excellent results but the rate of complication was lower with external fixation. Therefore external fixation using the one-half pin technique should be regarded as a primary method of stabilization for Grades II and III open tibial shaft fractures.

In April 1989 Fred Behrens published a paper giving a general introduction to the terminology, concepts, and classifications of external fixators. A clear distinction is made between characteristics typical of the three types of external fixators, simple, clamp, and ring, and those typical of the four standard frames that can be built with each of the devices. These four frames, the one-plane unilateral, two-plane unilateral, one plane-bilateral and two plane bilateral configurations, differ in the case of wound access they allow and their mechanical balance, particularly towards bending movements. Hybrids of different devices and frames may prove beneficial for stabilizing complex injuries.

Fred Behrens also described in his "General Theory and Principles of External Fixation" in 1989 a review of the capabilities and main complications of external fixators. In his paper he shows
how advances made during the past two decades have rendered the method safe, reliable, and predictable. Improved component designs, new techniques of pin care, the discovery of three basic concepts that govern the safe and effective application of pin and ring fixators, and the recognition that preoperative and long term planning are crucial to the success of the method have made external fixation the most acceptable, versatile, and gentle method for stabilization of complex injuries of soft tissue and bone.

David J. Maurer et al (1989) published a report on twenty-four patients who had a severe open fracture of the tibia that was initially treated by external fixation and subsequently by reamed intramedullary nailing. The external fixation had been maintained for an average of fifty-two days. The mean interval between removal of external fixator and intramedullary nailing was sixty-five days.

In five of the seven patients who had an infection at one or more of the pin sites; an infection later developed around the intramedullary nail. In comparison, only one of the seventeen patients who had not had a pin-site infection, had an infection later around the nail. An analysis of other variables, including the duration of the external fixation, wound coverage, other injuries, and the type of fracture, showed that none was a predictor of infection either at the pin sites or around the intramedullary nail.

They concluded that a pin-site infection that develops during external fixation is a contra-indication to the subsequent use of reamed intramedullary nailing in patients who have a fracture of the tibia.

Kwasny et al (1990) conducted a clinical and radiologic follow-up study of ninety-five patients of average age 69 years, with comminuted distal radial fractures who were treated with transfixation wires (Kirschner wire) through the base of metacarpal II & V and an above elbow Plaster cast. Two cases of early infections and four of Sušek's dystrophy were encountered. Follow-up studies which lasted an average of 29 months could be conducted on 77 patients. Using Sarmiento's ratings 27 patients fell into the very good category, 44 good, 8 fair and 2 poor.

P.A. Blachut, R.N. Meek, and P.J. O'Brien in 1990 reported forty-one open fractures of the tibial shaft treated with débridement and provisional external fixation, followed by delayed soft-tissue closure and subsequent intramedullary nailing with reaming. The average duration of external fixation was 17 days. The average time between removal of the fixator and intramedullary nailing was nine days.

Out of 39 patients, two subsequently had a deep infection healed with retention of the nail and without chronic osteomyelitis. There were two non-union and one delayed. Satisfactory alignment was achieved in 37 patients.

This sequential protocol for treatment, which involves a short period of external fixation and thus minimizes colonization of the pin tracks; yielded excellent results and low rate of infection.

Chhabda et al (1990) used an indigenous external fixator; an inexpensive locally fabricated external fixator was designed at M P Shah Medical College, Jamnagar, Gujarat for the treatment of open fractures of long bones. A total of 21 fractures of which 20 were treated using the indigenous fixator. Skin coverage by partial thickness skin grafts was obtained at an average period of 13.2 days. Partial weight-bearing
was begun on an average of 7.74 months and full weight bearing at the mean duration of 10.52 months. The functional results were excellent in 13 patients (65%), fair in five patients (25%) and poor in two patients (10%). These results compare well with those obtained by other workers using commercially available fixators.

Kotwal et al (1990) reported the study comprised of a total number of 223 patients treated with external fixators at Department of Orthopaedics, AIIMS, New Delhi in five consecutive years. The external fixators used were mostly of the AO (ASIF) tubular type, and the Wangner’s type and Anderson’s frame for leg lengthening. In all 223 consecutive cases of external fixation in 137 patients of acute trauma (Group A) and 86 patients with conditions other than acute trauma (Group B) were reviewed. In 74 compound tibial fractures union was achieved at an average of 16.4 weeks. In 34 cases an average of 4.2 cms of tibial lengthening was achieved while an average of 5.4 cms of femoral lengthening was obtained in seven patients. The complications included pin tract infection (84 cases), loosening of pins (27 cases), delayed union of tibial fractures (6 cases) and fracture through the lengthened segment (2 cases).

Anil Dhal et al in 1991 published a report on use of external fixation of intertrochanteric fractures of the femur. External fixation was used in the treatment of 154 intertrochanteric fractures of the femur over a period of eight years. Good fixation and early ambulation was achieved in all cases. Blood loss was slight. There were 12 deaths due to medical causes unrelated to the surgical procedure. Deep pin-tract infection occurred in six cases and late displacement of the fracture fragments in nine. The average time for union was 16 weeks.

The technique is simple, quick and inexpensive and causes minimal surgical trauma. All these features are particularly relevant where resources are limited.

Krettek et al (1991), treated ninety-nine open fractures of the tibial shaft with unilateral external fixation with or without supplemental lag screw fixation. They compared the results in 44 fractures in which only external fixation was used (control group) with those in fifty-five fractures that were stabilized with lag screws and external fixation, and they found no statistically significant differences between the two groups with respect to the time to full weight-bearing, the time to union, or the rates of delayed union; osteomyelitis, malunion, superficial or deep pin-tract infection, or loosening of the pins. The limbs in which the fracture was treated with external fixation and supplemental lag screws had more than twice the rate of refracture of the control limbs, and the percentage of fractures having supplemental lag screw fixation that needed bone grafting to achieve union was more than twice that in the group treated with external fixation alone.

They concluded that the routine use of supplemental lag screw fixation is not indicated in patients who have an open fracture of the tibial shaft that has been stabilized with external fixation.

Non-operative management is still the treatment of choice for closed fracture of the femoral shaft in children. Indications for operative interventions would include children with multiple injuries, severe soft tissue damage, cases where reduction is difficult to maintain; and children not suitable for management by traction.
Since 1984, 16 children (mean age 10.3 years) have had stabilization of their femoral shaft fractures by external fixation (Mono fixateur) in the Trauma Department of the Hannover Medical School. The external fixation remained in place for a mean of 63 days. Of the 16 children, 15 have been reviewed, with a mean follow-up of 28.2 months. No children who were completely managed with this fixation had any clinically relevant mal-alignment, but six cases had up to 2 cm difference in leg length.

Our observations and experience show that external fixation is a useful alternative for the operative management of femoral shaft fractures in children. It produces good stability, is less invasive, and allows early mobilization. In order to avoid difference in leg length, they recommend a good anatomical reduction with the external fixation being carried out as early as possible.

Mohsen and Foss in 1991 reported six cases of delayed union of fractures of the shaft of the tibia treated by the application of an external fixator on a daily case basis. All fractures united within 12 weeks. They used original A.O. pattern external fixator using two threaded rods and four Schanz screws which was inserted without disturbing the fracture other than to apply axial compression.

In 1991, A.J. Thakur and J. Patankar, reported a series of 79 open tibial fractures, which were treated with unilateral uniplanar tubular external fixators. Excellent stability allowed early weight-bearing. All comminuted fractures, with or without bone loss, and some transverse or short oblique fractures with intermediate fragments were treated by early bone grafting through a posterolateral approach.

The external fixator was dynamized as soon as periosteal callus was seen on the radiograph. Bone healing time ranged 11 to 40 weeks. Significant ankle stiffness occurred in 10.9% and leg shortening in 28%. Pin-tract infection was seen in 45% but was easily controllable with standard management.

The external fixation frame allowed excellent functional freedom for oriental patient to sit cross-legged and squat. Combined with early bone grafting, external fixation is an excellent method for the management of open tibial fractures.

Doomres et al. (1992) reported the use of wooden external fixator Doomres' experience at the unavailability of external fixator where their use was of paramount importance, due to financial or logistical reasons, inspired him to develop and use Wooden External Fixator while he was in a Red cross hospital in 1983. In between, the wooden fixator was used in hospitals of the following countries: Nigeria, Tanzania, Saudi Arabia and in a few other countries of Asia including India.

These fixators were used satisfactorily in the first series of 46 open fractures one of the mandible, 6 of the femur and 39 of the tibia. Of these, 21 were treated by metal fixator for first 2 days so that the metal fixator could be used again.

The different function of an orthodox fixator comprising stabilization, compression or distraction can also be achieved with wooden fixator if properly applied.

The advantages of the wooden fixator are:

1. The short time needed for its application.
2. Making good radiographs in two projection as wood is radiolucent.
3. The ready availability of wood and the ease of fabrication.
4 Cost only 2-3% of the cost of metal one
5 The shorter time spent in hospital.

The rigidity obtainable is certainly not as good as that with a metal fixator and adjustment of position limited.

2. Biomechanical Analysis

Since 1909, when Lambotte first reported the use of fixation screws placed on either side of a fracture and connected by a solid rod, surgeons have developed numerous different methods for percutaneous external fixation of fractures. These methods, described more fully by Anderson, Stader, Haynes, Charnley and Hoffmann, failed to gain popularity for various reasons, including high rate pin tract infection, instability, malalignment and soft tissue complications.

In 1938 a Swiss general surgeon named Raoul Hoffmann developed an external fixator with transfixing pins and connecting devices but this was also unstable. Thirty years later, in Montpellier University in France, Vidal et al. and Adrey in 1970 reported a modification of the Hoffmann fixator inspired by the results of a biochemical study of Hoffmann Osteotaxis, developed the Hoffmann-Vidal apparatus Vidal, using transfixing pins and a quadrilateral external frame. When used in the compression mode, the double frame increases the stability of the system by at least 40 times.

In 1972, Jorgensen performed the biomechanical analysis of the Hoffmann apparatus using human tibiae. The performance of the half pin, single frame device was found to rely on its configuration but no specific reference was made concerning the effect of material property on the rigidity of the system.

Burny (1968) and Burny and Bourgeois (1972) applied strain gauges to the connecting rod, to monitor motion at the fracture site.

Vidal et al. (1979) proceeded to study the resistance of the Hoffmann device to compression and to find out the most stable arrangement for tibial fractures. The biomechanical study was carried out by extensometric methods, gauges were fixed to the bar portion of the frame to record the deformities in various axes. The study was done by gradual loading in order to measure the deformities in flexion, pressure and torsion under pressure.

The results of the experiment proved that the best arrangement in the tibia was a double frame work external fixator using transfixing rod in frontal plane mounted on ball joints and united by four slide bars. Three pins were placed on either side of the fracture. The rods were threaded in mid portion which firmly grasped the cortical bone. They were of the opinion that tibia is the ideal bone for the use of external fixation by double frame, however they may also be used in other long bones.

In 1979, Chao et al. published three biomechanical studies. This study was initiated in Orthopaedic Biomechanical Laboratory of Mayo clinic. An attempt was made to quantitate the basic mechanical fixation of Hoffmann-Vidal instrument and its functional results on the fracture fixation using in vitro experimental models and theoretical analysis.

The first study analysed the fracture stability and compression strength attained by the standard...
quadrilateral configuration frequently used in tibia. The second study duplicated the experimental method of the first and to investigate a different geometric application of the device, the triangular configuration in femur fractures. The third study was strictly theoretical. It was done by modeling the fixator system as a two-dimensional structure to quantitate the internal stresses and deformation of each element involved.

Based on these experiments the vertical side bars were found to be stiffer, with rush roods to be intermediate and the Hoffmann pins the weakest. The weakest mode of H-V device was in Antero-posterior bending and this could be increased by increasing the number of pins and reduction of pin group separation and pin lengthening. It was as also observed that by hand tightening of the compression screws the compression force can easily reach 45 kg, and with the aid of tightening bar up to 100 kg. Once H-V apparatus is applied securely the ability to reduce and realign fracture fragment by adjustable screws becomes very limited.

When fewer pins were used individual pin stress would be increased significantly which would lead to permanent deformation. Increasing the size of pins could effectively decrease both the pin stress and the fracture site displacement.

Aalto and Karaharju in 1981 tested the mechanical stability of 4 external fixation devices which are in clinical use. The human osteotomy tibial bone was used for testing the fixation stability. The torsion and bending resistance and axial deformation in compression were measured. The stability was tested separately with the bone fragment in contact and then with the gap between them.

In their study the stability of mounting with one tie bar was found to be approximately one third to that having mounted with two bars. They different inferred that the external fixation devices in general could not be considered rigid, and that this elasticity was of no clinical importance in practice. The weak joint of the device were found to be connecting joints between the bars and the transfixing pins, which gave way and the transfixing pins which bent under stress. They were of the view that rigid external fixation device could not be constructed and more over it did not seem to be necessary.

Michael T. Mecoy et al (1983) reported a comparison of Mechanical Performance in four types of external fixators at the 26th Annual Meeting of the Orthopaedic Research Society, Atlanta, Georgia, February 1980. The Hoffmann-Vidal triangular apparatus for fracture fixation of the femur, the Volkov-Oganesian device with Steinmann pins in tension, the Kronner device with a plastic elliptic frame, and the Roger-Anderson apparatus (both standard and compression-distraction design) were studied based on loading and analytic methods established previously at Biomechanics Laboratory, Department of Orthopaedics, Mayo Clinic.

The results were compared with those for the standard Hoffmann-Vidal quadrilateral configuration. The Kronner device, with five connecting bars, was stiffest under most loading modes, closely followed by Hoffmann-Vidal quadrilateral apparatus. The standard Roger-Anderson device demonstrated average rigidity, its new design with compression distraction capability was relatively weak. All devices showed an apparent weakness in antero-posterior bending. The Volkov-Oganesian design demonstrated low overall stiffness but was the most effective apparatus in resisting antero-posterior
bending. External fixators provide effective compression at the fracture site, and the amount of compression is proportional to the stiffness of the apparatus.

Briggs T. Brain and Chao (1982) analyzed the mechanical performance of the standard H-V external fixation apparatus for tibial fracture using different geometric and material variations of the basic configuration. The fixation stiffness properties were quantitated to provide objective comparison. The results have shown that the bone-pin interface is the least stiff link in entire structure particularly under the antero-posterior bending mode. Rigidity of the device can be substantially improved by increasing the number of pins, using full threaded pins with a larger diameter, decreasing side connector rod distances, and increasing pin-separation distances in each pin group.

Symmetrical tightening of the compression screws by hand is sufficient to produce compression of bone at fracture site. The use of Titanium pins tends to reduce stiffness, but using a frame made of Titanium can significantly decrease the weight of the apparatus without decreasing its stiffness.

In clinical use of external fixation apparatus, the rigidity of fracture reduction can vary substantially according to the configuration of application.

Fred Behrens et al reported bending stiffness of unilateral and bilateral fixator frames in Clinical Orthopaedics and Related Research in Sept 1983. The structural and geometric fixator properties that best neutralize the prevailing antero-posterior and transverse bending moments at a tibial fracture site were analyzed in anatomic specimens. Clinically and mechanically, anterior unilateral frames were most effective, particularly when applied with relatively stiff components with a maximal spread between the pins in each main bony fragment and with placement of the longitudinal rod close to the tibia.

Etter et al (1983) published an experimental biomechanical studies on 17 fresh male cadaver tibiae and clinical studies of 126 open fractures of lower leg between 1978 to 1980. External fixation is the treatment of choice for fractures of the leg involving severe damage to the soft tissue. Each of the various patterns of application has advantages and disadvantages. Based on various biomechanical studies and clinical experience, the authors use a right angle arrangement for the screws. If the type of the fracture permits, internal and external fixation may significantly increase stability. During the period from 1978 to 1980, 56 patients with second and third degree open fractures were treated. A combination of external and internal fixation was used in 42 patients. Of the 44 patients re-evaluated at follow-up examination, 19 had returned to unrestricted weight-bearing within 19.8 weeks. If no sign of bony union are noted 10 to 12 weeks after the initial operation, cancellous bone grafting and internal fixation instead of external fixation are indicated. 23 patients were fully weight bearing an average of 14 weeks after internal fixation and bone grafting. Two patients had difficult problems and did not return to full weight-bearing until about 45 weeks after operation. The stability of three-dimensional external fixation was significantly higher than that of frame-type fixators. Stability was significantly increased by the application of a lag screw. The insertion of Schanz screws at 90 degrees to each other in medial and anterior aspect of the tibia found greatest stability.

G. Mayer and E. Wolf in 1983 reported the results of animal experiments to examine the histology.
of fracture healing in osteosynthesis with external fixation and compression. In their study, tibial osteotomies in sheep were stabilized with nail fixation and wire fixed external devices with static longitudinal compression. The mechanical situation of osteotomies was checked via continuous measurements of intrafragmentary tension used as functional indicators of stabilization. Simultaneously, the test animals were marked by polychromatic fluorescent pigments.

The histological findings made at the site of osteotomies showed that the temporal and local progress of ossification was influenced by the degree of stability of osteosynthesis. They inferred that under stable osteosynthesis primary bone healing occurred, resulting in callus free osseous healing and in unstable due to interfragmentary instability and the consolidation of these osteotomies was accompanied by formation of surrounding osseous callus of varying thickness.

Chao et al. in 1989 published the effect of rigidity on fracture healing in external fixation. The knowledge of the basic biomechanics of external fixation is necessary to obtain the full benefits of the technique for bone fracture treatment. The rigidity of external fixation, including pin-bone interface stresses, is discussed and bone healing and remodeling under different fixation stiffnesses and fracture gap conditions are described. The rigidity of fixation ultimately depends on the biomechanical characteristics of the fracture, the accuracy of reduction, and the amount of physiologic loading. Comparative experiments using a canine tibial fracture model have suggested that fixation rigidity is important in early bone healing and in the prevention of pin loosening. Bone union can be achieved under external fixation through different pathways, ranging from callus free gap healing under a rigid neutralization configuration to direct contact healing with periosteal new bone formation under axillary dynamized stable fixation. Cortical reconstruction by secondary osteous seems to be important for the ultimate strength of the bone union.

Broekhuizen et al. in 1990 performed a laboratory study using external fixator on perspex rods designed identical to femur, with fractures without contact, to justify whether external fixator should be applied and grounds for same, and observed it to depend on a number of fractures. It is rarely considered to be the treatment of first choice. External fixation can, however, be indicated in certain circumstances. Looking for optimal rigidity in such cases they tested and compared the stability of 14 different femoral external fixators in an experimental model. It was found that the weight of the different frame varied widely. Movements of between 1 mm to 4 cm and rotations varying from almost 0 degree to 16 degree were measured at the experimental fracture site, based upon the geometry of an adult patient. In view of this finding primary bone-healing would not be expected to occur, since it depends more stability than external femoral fixation can offer. A relative simple two-dimensional (unilateral) frame can be as rigid as a three-dimensional one, in response to all but transverse loading.

**Improvement of External Fixation:**

With ideas borrowed from Malgaigne, Parkhill, and Lambotte, many other external fixation systems were introduced. Numerous problems also appeared, e.g., pin tract infection, inadequate stability,
and difficulties in realignment, because of the high incidence of significant complications associated with that method of treatment, fixators were generally unpopular with American Surgeon for 20 years, even after World War II.

Research for the improvement of external fixators has three essential aims:

1. To attain better tolerance for pins and to increase anchorage,

2. To improve the handiness of the apparatus to allow correction of displaced bony fragments,

3. To provide complete stability in all planes, as with internal fixation.

**Pin Improvement**

The wooden screws used by Rigau and Parkhill were not used for long. All of the currently used pins were developed from Lambotte’s fully threaded pins. The first iron models were made later in stainless steel; they were better tolerated and use of a borer permitted their insertion without predrilling. They were the first self-drilling and self-tapping pins.

In 1914 Javara and in 1931 Boever proposed pin guîtes for a better orientation during insertion.

In 1932 Henri Judet, the first to insert the pins on both cortices of bone, showed the importance of skin necrosis and to avoid pin tract infection. His external fixator was later improved by his sons, Robert and Jean Judet (1958).

Other surgeons proposed the use of transfixing pins to increase anchorage. Lambret of Lille in 1912 designed a simple full-frame fixator for the tibia using transfixing pins and introduced the principle of continuous skeletal distraction. Using this concept, Putti in 1921 followed by Abbott and Basworth, performed the first limb-lengthening after osteotomy. In 1973 Bonnel redesigned transfixing pins to grasp firmly both cortices to bone.

**Improvement of Handiness**

It was possible to change the position of the fragment with Lambotte’s or Parkhill’s apparatus, but only in one plane. The “Crampon extensible” of Chaltiere permitted compression of the fracture site but only in one plane. Ombreanne revised a fixator for pediatric fractures, based on the malleability of the frame, but this malleability decreased its stiffness.

Articulations connected to the bars of the fixator or to the junction of the pins and bars were the first improvement. Manipulation with these articulations was sometimes possible in two, but never in three planes.

The second improvement was the possibility of closed manipulation to secure reduction of the fracture. In 1934, Roger Anderson of Seattle revised an apparatus using transfixing pins connected to movable metal yokes. Anderson added pins in plaster after securing reduction in a “Fracture Robot” attached to the pin groups, permitting multi-planar adjustment of fracture fragments. Later, Anderson revised an external fixator, thereby eliminating the plaster cast. Meanwhile, a veterinarian surgeon, Otto...
Stader (1937) designed and brought into regular clinical use a half-frame fixator that permitted reduction of fracture fragments in three planes independently. A similar device conceived by Haynes, H.H., was inspired by Anderson’s device.

A later improvement was realized in 1938 by Raoul Hoffmann, who was also a master carpenter and doctor of theology. He devised an external fixator and incorporated a universal ball joint connecting the external bars of the fixator to strong pin-gripping clamps which allowed fracture reduction in three planes with the fixator in place. Hoffmann coined the term “Osteotaxis” (from the Greek to put the bone in place). Secondary corrections were possible with this fixator. Furthermore, Hoffmann substituted a sliding compression-distraction bar for the rigid bar connecting the pin-gripping clamps, by this way interfragmentary compression or limb-length restoration could be achieved.

**Improvement in increasing stability:**

Complete stability of external fixation can be obtained by direct action of the fracture site or by increasing the stiffness of the apparatus. It is possible to achieve interfragmentary compression on the fracture site.

In 1959 Robert and Jean Judet showed the utility of compression and practiced it with an elastic system attached to the pins of their external fixator. Most currently used fixators also incorporate a compression system.

- Improvement of the stiffness of the apparatus can be obtained by increasing the size or number of the components of the external fixator. To enlarge component, Wagner uses Schanz pins - 6 mm with a very large quadrangular connecting bar. Other workers, including Lortat-Jacob, have proposed enlargement of the size of the component. However, pin size is limited to approximately 20 percent of the bone diameter to avoid pin hole fractures. The multiplicity of the components of the fixator and their configuration can also increase stiffness.

In 1911 Lambret designed the first simple full frame fixator. Charnley in 1948, followed by the ASIF, designed similar frames. In 1935 Lamare and Larget used two external fixators placed in two perpendicular planes and aligned by two horizontal bars. The French army’s fixator was designed according to these principles. In 1967 Jacques Vidal proposed a double-frame mounting. According to Chao, six possible types of frame configuration were distinguished on the basis of geometric configuration.

1. The unilateral frame is the simplest configuration e.g., Parkhill’s bone clamp, Lambotte fixator, Starter frame, Hoffmann frame and Wagner frame.

2. The Bilateral frame has two bars on both sides of the limb using transfixing pins e.g., Anderson, Haynes, Day frames or using half-pins as in Lamare and Larget devices.

3. The Quadrilateral frame has four bars, two on each side of the limb connected to pins that transfixed the bone, e.g., Vital-Achey frame.
### POSSIBLE DESIGN OF EXTERNAL FIXATOR

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PLATE-5