REVIEW OF LITERATURE
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In the age when Homo sapiens are going up
and down the moon, living on artificial hearts and
banking on nuclear weapons for their survival, the
orthopaedic surgeon faces a rather basic but formidable
question - Is it better to treat a fractured bone by
rigidly immobilizing it, or by allowing it to move;
and if so, to what extent?

Since his origin, man is facing the problem of
injuries and accidents, and is trying to cope up with it;
so the history of surgery and particularly recognition of
fractures with their treatment dates back, perhaps to the
advent of man itself on this planet. Since no methods
existed in those times to record events, there are no
records of methods applied for fracture treatment during
that period. Some glimpses however, are possible through
the various scriptures which came into being subsequently.
The evidences of Egyptologists prove beyond doubt that
many thousand years ago, splints were used to fix broken
bones in such the same manner as they are being used today.

In our country earliest references to the subject
of healing of bones are found in Atharva-veda some 3000
years B.C. Later on treatises of Charaka and Sushruta,
originally written about 1000 years B.C. (Kawamori, 1967),
deal with the diagnosis and treatment of various types of
fractures and dislocations.

Sushruta Samhita contains in it essence of all
that was known with regard to surgery and fundamental
sciences closely related to this art. The orthopaedic
treatment, which was based upon rich experience of the
surgery was rational and at times ingenious. Sushruta
has described the fracture as 'Kanda Bhaga' and described
6 types of dislocations and 12 types of fractures, while
dealing with diagnostic considerations (Hindu Athana,
second Cento of Sushruta Samhita quoted by Bishal, 1977).

The fractures, after a correct diagnosis, were
treated among other things, with traction by means of a
pulley (Chakra).

Turkish Empire (1790) reported that the setting
of bones was practised by enclosing the broken bones in
case of plaster of paris.

Matthysen (1852), a Dutch man was the first to
device Plaster of Paris bandages by rubbing the powder
into coarse cotton material on a table. He popularised
the use of plaster of paris bandages and recommended that
the fractured limbs were to be immobilised with one joint
distal till complete union occurred. Since then, a number
of treatments of fractures, particularly for those of both
bones femora, have been devised from time to time.
Till date there is unanimity of opinion regarding the difficulty in obtaining satisfactory results in displaced diaphyseal fractures of both bones in forearm but considerable ambiguity has been prevailing over the best line of management and regarding the various aspects of a particular form of treatment. Broadly, the methods have been divided into two categories - conservative and surgical.

The results of closed treatment in most series have proved unsatisfactory in a high percentage of cases. However, the report of Sarmiento & associates (1975) and more recently, the excellent book by Sarmiento & Litala on the use of early functional bracing for forearm fractures are significant exceptions.

Many surgeons have preferred to treat these fractures conservatively. Evans (1965) dealt with the problem of rotational malalignment by recommending the use of 'bicapital tuberosity view' for closed reduction. Because the surgeons have no control over the proximal radial fragment with closed methods, he must bring the distal radial fragment into correct relationship with the proximal one. Ascertaining the rotation of the proximal fragment from the tuberosity view prior to reduction gives some idea of how much pronation or supination of the distal fragment is needed. The tuberosity view is made
with the X-ray tube tilted 10° towards the olecranon, with both humeral condyles and the subcutaneous border of the ulna flat on the cassette. According to Evans, pre-reduction bicipital tuberosity view gives an idea as to how much of the rotational deformity is to be corrected and a post-reduction view ascertains whether or not the rotational deformity has been corrected. This is done by comparing the post-reduction view with a diagram showing the prominence of the bicipital tuberosity in various degrees of pronation and supination or by comparing with a bicipital tuberosity view of the opposite elbow in a given degree of rotation.

Stuck & Thompson (1949) emphasized that most fractures of both bones of forearm can be treated satisfactorily by closed manipulative methods or by some form of traction. They further stated that there is a strong tendency towards non-union of fractures treated by open reduction and internal fixation because extensive tissue destruction required in such procedures interferes with the blood supply to the fracture site and this delays the healing of bone. Boyd, Lipiński & Wiley (1961) supported this view.

Key & Conwell (1951) found displaced forearm bone fractures amongst the most difficult ones to treat. They were in favour of at least two closed manipulations
and surgical treatment to be used only as a last resort. Cave (1956) agreed with this view.

Watson Jones (1955) preferred to reserve surgical treatment only for those patients in whom it was not possible to get satisfactory closed reduction. According to him infection following open reduction and internal fixation may prove to be disastrous for the limb of the patient.

Böhler (1956) stated that breaking and bending of screws, plates and nails is often soon to result in failure of treatment by open reduction and internal fixation. He therefore preferred treatment by closed methods.

According to Charnley (1961), closed method of treatment can give excellent results but the element of luck is rather prominent.

Ralston (1967) advocates closed manipulation and plaster of Paris fixation and states that most both bones fractures with complete displacement can be treated successfully by this method. According to him, most surgeons are not familiar with the correct technique of closed manipulation and plaster immobilization, resulting in poor results by conservative methods.
Belton & Quinlan (1952) reported that average time of union of these fractures is more for surgically managed patients as compared to those treated conservatively.

Non-union rates reported by conservative treatment have been quite low with reports of 6% by Böhler (1956), 4.4% by Belton & Quinlan (1952) and 6.3% by Deburun (1962).

Sarmiento, Sinclair & Cooper (1975) tried functional bracing of forearm fractures. Sarmiento & Letts (1981) have reported good results with their method of conservative treatment by functional bracing. In support of their preferred method of treatment, they stated that, although displaced fractures of both bones of forearm are difficult to consistently reduce and maintain reduced by non-surgical means, it has become clear that careful attention to details during the reduction and initial stabilization with above the elbow casts permits adequate reduction in many instances; thereby eliminating the need for surgical intervention which is associated with various complications such as infection, synostosis and non-union. Incidence of refracture following removal of plate although not high, can be significant. They further stated that anatomical reduction is not must for restoring good function. According to them, angulation of less than 10° of either or both bones of the forearm in any direction does not produce a major limitation of
promotion or aspiration. Also, the loss of radial bow
does not necessarily produce major impairment of function.
Cosmetic results which might be important to the patients
are also better as compared to the operative treatment.

Anderson (1964), Sarmento & associates are
highly skilled in the use of functional bracing over a
long period of years. This results have not been duplicated
by others.

Anderson further stated, as a practical matter,
I rarely attempt closed treatment for displaced fractures
of both bones of the forearm in adults, unless some other
condition of the patient prohibits surgery. The results
are too uncertain and the period of immobilization too long.

On the other hand, the proponents of operative
management have pointed out shortcomings of conservative
management and the benefits of surgical treatment of
displaced fractures of forearm bones.

Depalma (1970) stated “over the past decades
there has been a considerable change in the philosophy
of management of fractures of both bones of the forearm.
In the hands of most orthopaedic surgeons, closed reduction
has been unsatisfactory since this method of treatment
represents a compromise in which malposition is accepted
to ensure union (Sage, 1939).
According to Marek (1961), Evan’s results obtained by conservative methods have never been duplicated in United States. Burwell & Charnley (1964) have noted that satisfactory initial reduction of displaced diaphyseal forearm fractures in adults may be obtained but the technique is not easy and two or more trial manipulations under anaesthesia and radiological control may be required. Should satisfactory reduction be obtained, redisplacement frequently occurs (Perkins, 1950; Woldsworthy, 1961). Further manipulation is seldom successful (Bolton & Quinlan, 1952; Charnley, 1961). Even the undisplaced fractures particularly of lower shaft of radius and upper shaft of ulna show progressive angulation in plaster (Smith, 1959). The decision regarding timing of operation is difficult, particularly when displacement has progressed slowly over period of weeks (Watson Jones, 1955).

Muller et al (1979) have stated that anatomical reduction and restoration of double bow of radius is essential to achieve good range of pronation and supination. Depalma (1978) said that serious irreversible complications may occur as a result of prolonged period of immobilisation in plaster such as flexion contractures of the elbow and shoulder joints, marked restriction of rotatory motion of the forearm, Sudeck’s atrophy and formation of dense scar tissue around the malunited fragments which makes subsequent surgery very difficult.
Allgower & Spiegel (1979) have supported the views expressed previously by a number of surgeons (Nichols, 1961; Marek, 1961; Jinks & Co-workers, 1960) and have favoured rigid internal fixation as the treatment of choice. According to them, rigid internal fixation decreases fracture disease, that is, muscle atrophy, joint stiffness and bony demineralization by early mobilization without external support. This view was lent support by earlier reports of unsatisfactory functional results, following prolonged external immobilization.

Knight & Purvis (1949) reported 74% unsatisfactory results and Salter & Wainman (1952) 41% unsatisfactory results with closed manipulation and plaster immobilization.Hughston found 92% with unsatisfactory results unless open reduction and rigid internal fixation were performed. In view of uncertain results and prolonged period of immobilisation by conservative methods, Anderson (1964) prefers open reduction and internal fixation for both bones forearm fractures. Sisk (1967) stated that due to complex angulatory as well as rotatory forces acting on both bones of forearm, conservative treatment results in frequent malunion and non-union. He adds in view of this, open reduction and internal fixation is deemed to be the best method of treatment of these fractures. Corgan and Teppner (1968) and later Grewe & Sverman Jr (1980) pointed out the economic advantage of no external immobilisation.
They stated that the patient benefits from comfort, and convenience of the absence of external immobilisation device following internal fixation and has an increased ability to perform everyday tasks and to regain gainful employment.

Various modes of fixation have been used over the years to fix these fractures after open reduction. Open reduction without internal fixation has all the disadvantages of both open and closed treatment and has no place in the modern treatment of fractures of both bones of forearm in adults.

In the early 1900s, Lane of London, and Lambotte of Belgium, reported the use of plates on diaphyseal fractures. However, metal reaction led to frequent failures until modern metals for implantation were introduced in 1937 after the work of Venable & Stuck on electrolysis. Campbell used autogenous tibial grafts fixed to the radius and ulna with bone pegs or screws for acute fractures as well as non-unions. Some of these were successful, but unless external immobilisation was very prolonged, the grafts often developed fatigue fractures before they were revascularized.

Intramedullary fixation was described by Nicolayevm (1897) and Belhot (1906). Earlier attempts were with small pins and not too successful, Sape (1908) stated.
commenting on poor results of Rush pins & Rush (1937) and Lambrinudi (1939) who used Kirschner wires for intramedullary fixation of these fractures. After medullary nailing became popular for fractures of the femur in the late 1940's, various devices for medullary fixation of radius and ulna were used (Anderson, 1984).

Stuck & Thompson (1949) reported union in seventeen out of nineteen patients treated by them using Kirschner wires and Steinmann pins for intramedullary fixation after open reduction. Smith & Sage (1957) reported a series of 555 fractures collected from all over the country in which some form of medullary fixation had been carried out. The devices included - Rush pins, Kirschner wires, Steinmann pins, Lottes forearm nails and Kuntscher V. nails. The results were discouraging. Non-union resulted in over 20% of the fractures. This figure exclude Kirschner wires which failed in 30% of the cases. Even in the fractures which united mal-union and poor function were frequent. The radial bow was not maintained and the use of a round pin in a round medullary canal could not control rotation of the fragments. Cadee reported a non-union rate of 16.6% in forearm fractures treated with Rush pins.

Sage (1959) published his study of the anatomy of the radius and introduced Cadee triangular forearm medullary nails. The nails for the ulna are straight and
are inserted in a retrograde manner. The nail for the radius is bent to aid in maintaining radial bow. It is introduced from the radial styloid and driven proximally.

Sage reported good results with his nails. Non-union resulted in only 6.2% and delayed union in 4.9%. Other triangular or rectangular nails for the forearm bones were introduced by Ritchie & Street. These also grip the cortex well/control rotation but do not preserve the radial bow as well as the Sage nail. Sage nails are not recommended for fractures of the distal third of the radius after medullary canal has begun to enlarge. Also they should not be used if the medullary canal is less than 3 m.m. in diameter. But he mentioned that in the treatment of radial fractures, the technique is not simple, nor is uniformly efficient. He also recommended routine autogenous iliac bone grafting.

Even after better metals became available, many of the early plates used for fractures of the radius and ulna were of poor design. Failures were frequent because adequate fixation was not achieved. For a time the use of plates and screws for the internal fixation of diaphyseal fractures in general fell into disfavour. Many surgeons treating fractures thought that fixation with plate and screws held the fracture distracted and caused delayed union and non-union (Anderson, 1980).
The first bone plate for fracture treatment was reported by Hansmann in 1886. This report was followed by Lambotte in 1909, Sherman in 1913 and by Lane in 1914. Each plate showed evidence of increased strength and tissue acceptance. The Sherman plate was significantly better than the weaker Lane plate because of its difference in contours and stronger steel (Vanadium). This plate, with round screw holes, was commonly used for many years, followed by a series of slotted plates.

The era of the slotted plate was introduced by Townsend & Gilfillan (1943), followed by Eggers (1946) and Callisen in 1950. Townsend’s technique was to apply the plate loosely, then, while an assistant impacted the fragments manually, the screws were tightened. Eggers proposed using the slotted plate (or contact splint, as he preferred to call it) with loose screws, and thereby relied on to the longitudinal muscle pull acting across fracture site to compress the fragments and hold them in close opposition, hoping that this process would encourage early union. After the first few days, fibrous tissue and callous grows into the slots so that sliding is no longer possible. Eggers plate was a much stronger plate than those used previously, and it provided better fixation. Jiahian and co-workers reported a series of 145 forearm fractures in 1989 in which 145 slotted plates and 20 medullary nails had been used. The overall non-union
rate was only 4.3%. They concluded that the results were best when a slotted plate was used for the ulna and either a slotted plate or a Rush pin for the radius. The Callison plate with shorter slots is a variation of the Egger's plate and was used in a similar manner.

Active compression created by a bone plate was introduced by Denis of Belgium in 1949. He used an axially-oriented screw within the plate to compress the fracture fragments. Denis called attention to the fact that diaphyseal fractures treated with these plates healed with very little peripheral callus, a phenomenon which he referred to as primary fracture healing. Venable (1951) and Baroua & Hermann (1952) described other compression plates with two parts in which a cylindrical bolt forced the fragments together. All three plates were awkward and ineffective in their compressive force. The introduction of Muller's plate in 1950 was a significant improvement over the Denis plate with its extraneous compressive device and improved screws provides better compression.

The Begby plate was the first so-called self compression bone plate. The device was used at Mayo Clinic in 1936 to study compression as it relates to fracture healing (Begby, 1957, 1977). Many variants of this self compressing plate are in common use today. The main efforts to improve these have concentrated on more rigid fixation proportion, assume with better holding power.
screws with more precise fitting (Perren et al, 1969). These attempted improvements were designed to require less cast fixation, thereby permitting earlier movement of the adjacent joints, shorter healing time and better restoration of joint motion.

Compression for the purpose of healing of bone was first used by Kay (1932) for arthrodesis of knee joint. He used percutaneous pin above and below the prepared surfaces of the knee joint with external tumbercables. The tumbercable arrangement had the feature of dynamic compression force. When absorption and loosening of the fixation occurred, the tumbercables were lightened to maintain compression and close bone contact. Roger Anderson (1934) used a similar principle to treat fresh fractures of long bones.

The advantage of compression for fracture is to create close apposition of the bone fragments and to hold them rigidly together. This reduces the area of essential new bone formation, and protects the fragile, invasive vascularization necessary to precede bone callus.

In about 1950, Muller, Alliger and Willenegger developed what is now known as the ASIF (formerly AO) compression plates. The technique for using this plate and other recommended techniques of the Association for the study of internal fixation were published in 1965.
The plate is a modification of the plate of Denis but is much stronger, so more compression can be obtained (Anderson, 1964).

Lettin (1969) and Paavolainen and co-workers in 1978 have reported on the effects of rigid internal fixation of fractured bones. Lettin stated that callus formed in plated bones was firm and inelastic whereas in controls healed by plaster immobilization, it was more pliable suggesting that latter was fibro-cartilagenous callus and the former woven bone. Paavolainen & co-workers reported that bone subjected to rigid plate fixation maintained a nearly normal mineral and collagen content during the process of continuous remodelling by which the bone strives to adopt itself to the implant and to minimize the adverse effects of plate. Denham (1969) said that compression of bone ends in the fracture assisted union. Compression was effective simply because it closed an obvious gap, thus improving reduction, increasing fixation and lessening the need for new bone formation. Schenk & Willenegger (1967) showed in both dogs and humans that fracture could unite by primary bone healing if the fragments were rigidly fixed and there blood supply disturbed as little as possible so that under these conditions resorption and bone formation occurred simultaneously. Verren et al in 1969 showed that osteotomized rabbit tibial rigidly fixed with compression plates could heal by capillaries and haversian systems
extending directly across the osteotomy site producing cortex to cortex healing. Bassett & Rudi in experiments in vitro showed the mesenchymal cells under compaction in the presence of a high oxygen tension might differentiate into osteoblasts, whereas under tension, distraction, or low oxygen concentration they might differentiate into cartilagenous or fibrous tissue cells.

Allgower & co-workers in 1969 reporting on dynamic compression plate said that less exposure was required for fixing these plates as no external tension device was required during fixation. Also these plates provided good stability and more homogenous appearance of healing fracture site. Naiman, Schein & Siffert (1970) reported 100% union rate in their study with the use of ASIF compression plates in 26 patients. Dodge & Cody (1972) reported 100% union rates in primary internal fixation using ASIF compression plates. With the development of superior forms of internal fixation, in routine cases involving intelligent and co-operative patients, post-operative plaster immobilisation can be dispensed with and early motion can be instituted (Gross, 1972). Taipner & Mani (1980) while comparing the use of double plating versus single compression plate in forearm fractures concluded that the new compression plates provided as good a fixation as double plates without the disadvantages associated with double plating such as
extensive exposure, more stress riser effect of implants and screw holes and increased operating time.

1960 onwards surgeons began using ASIF (formerly AO) compression equipment in clinical practice. Campbell Clinic and city of Memphis hospital from 1960-1970, 244 patients (216 with closed and 28 with open fracture) had 330 acute diaphyseal fractures of the radius and ulna which were treated by ASIF compression plates and followed from four months to nine years. Overall rate of union for the radius was 97.9% and for the ulna 96.3%. Excellent functional results were also achieved. With compression plate fixation early active motion is possible.

ASIF compression plates therefore, provided a successful method for obtaining union and restoring optimum function after acute diaphyseal fractures of forearm. Semitubular plates (D.C.P.) are types of compression plates. These plates are semi-tubular in cross section and have oval holes for screws. They are useful in subcutaneous locations. These plates are used in fractures of forearm, non-union of clavicle and to fracture of fibula.

Due to there semi-tubular shape they are better fixed according to contour of forearm bones to provide help in the mobility of forearm bones and do not interfere with the rotational movements. Very active mobilisation can be followed with the semi-tubular plates which will
lead to differences in long term results. Early active
motion helps to prevent muscle atrophy and joint stiffness.
Thus, dynamic compression plates are best method at present
for the fixation of fractures of forearm.

Besides the differences on the type of implants
to be used, views have differed regarding other aspects
of surgical treatment too. Smith (1959) in his studies
found that patients in whom the internal fixation had been
done in less than one week after injury had significantly
higher non-union rate of 22% than those in whom it had
been delayed for three weeks following injury. Lam (1964)
supports Smith's view. Early operation according to them,
further compromises the already severely affected blood
supply to soft tissue structures surrounding these
fractures. Rosesser and Keptt (1961) found delayed
surgery to be an important factor in obtaining primary
union. Nick (1964) contradicted Smith's view and said
that Smith's view regarding delayed plating seems to be
valid when applied to the results of ordinary plating but
it becomes less important in case of rigid plating.
favoured early internal fixation for forearm bone
fractures.

Controversy also exists regarding the extra-
periosteal or sub-periosteal fixation of plates. Some
surgeons (Nick, 1964; Charley, 1964) preferred to apply
the plates extra-periosteally. Anderson (1984) also stated that periostea should not be stripped to expose the bone. Less damage is done if the muscle is dissected free from the periostea and the plate is placed on top of the periostea. Lesker and Whiteside (1978) based on their own work and experiments of Susman (1960) are in favour of extraperiosteal fixation of plates. Sisk (1987) advocates minimal stripping of the periostea from the bone without dissecting the muscle away from the periostea. He added that placing the plate beneath the periostea on the bone should produce less injury to the local blood supply.

Views have also differed over the role of external immobilisation following open reduction and internal fixation. Watson-Jones (1955) favoured use of external plaster immobilisation following internal fixation till fracture united. DeBuren (1962) stated that plating without subsequent immobilisation in plaster is a method to be abandoned. Cowie (1957) did not use post-operative plaster and reported good results. Cruesa (1973), Anderson (1984) and Sisk (1987) preferred to assess each patient individually based upon the patient's intelligence, co-operativeness, type of fracture and adequacy of fixation. In general, if fixation is good and patient is co-operative and intelligent he is not given post-operative immobilisation but was advised to do only light work without any lead
bearing till the fracture unites. Otherwise, the patient is made to exercise gently (under supervision) the joints and muscles of the operated limb, till skin sutures are removed. After that, he is given plaster immobilisation till the fracture shows signs of union.

Hadden, Rueschauer and Seegl (1984) have pointed out that although compression plating leads to excellent results in a majority of patients, it is also associated with serious complications in a minority. Surgeons utilising the method must be able and willing to treat these complications. Anderson and co-workers (1975) reported that most of the failures were due to errors in technique or infection. Anderson (1984) stated that before compression plating is undertaken, the surgeon must be thoroughly familiar with the technique. A complete set of equipment must be available and rigid aseptic technique must be enforced on the operating room. Midula and Gustilo (1984) reported seven refractures of 32 forearm fractures in 23 patients following plate removal. Sisk (1987) stated that refractures are less if a rigid compression plate is removed after one year and the longer the delay, the less is the chance of refracture. He did not recommend routine removal of forearm plates in the average patient.

Sago (1985) stated that achieving union is of paramount importance. Over the years, however, the emphasis
has shifted to achieving union with good function. In
words of Grace and Everman Jr. (1980) "success in the
treatment of fractures of one or both bones of the forearm
means that union of fracture is achieved with minimum
restriction of motion in forearm, wrist and elbow and with
restoration of good muscle strength without pain. The
merits of any treatment regimen should be judged on these
criteria because failure to achieve any one of them will
compromise the functional results.