DISCUSSION

The management of choice of displaced diaphyseal fractures of both bones of the forearm in adults has been controversial. Proponents for surgical as well as conservative management have highlighted the merits of their preferred method of treatment and demerits of the other methods. Over the years emphasis has shifted from achieving union to achieving union with good function in the injured limb. Some surgeons like Connolly (1930), Sarmiento & Latto (1981), prefer conservative management. High percentage of unsatisfactory results by conservative methods have been reported by most of the surgeons (Knight & Busis, 1949; Bolton & Quinlan, 1952; Burwell & Charney, 1964 and Cruss, 1973).

Pioneering work has been done in improving the metal quality by Venable (1937) and on the concept of compression fixation by Denis (1949), Venable (1951) & Bagby (1958). Denis developed the first compression plate for fixation of fractures of the forearm, and noted that with axial compression and rigid immobilization, a fracture heals with minimum roentgenographic evidence of callus formation, a process that he called healing 'Soudure autogène' or primary bone healing.
There are four areas of osteogenic potential in any healing diaphyseal fracture: the periosteum, the endosteum and medullary cells, the haematoma, and the cortical fracture ends. A common misconception is that the cortical ends undergo resorption back to a point where the cortex is viable.

Schenck & Willenegger showed in both dogs and humans that fractures could unite by primary bone healing if the fragments were rigidly fixed with the least blood supply disturbed as little as possible, and that under these conditions resorption and bone formation occurred simultaneously. Ferren & associates showed that osteotomized rabbit tibias rigidly fixed with compression plates could heal by capillaries and haversian systems extending directly across the osteotomy site producing cortex to cortex healing. Anderson & co-workers (1981) observed that with rigid fixation by a compression plate union occurred in medullary canal with no cartilagenous or enchondral phase. They also noticed that microscopic bone formation and bone resorption occurred simultaneously in the cortical ends but without gross resorption visible on the roentgenograms.

Charnley showed that when compression was applied to large cancellous surface (as in arthrodesis of the knee), extremely rapid ossification and union took place. In the case of cortical surfaces, however, he stated that excessive compression may lead to lysis of bone. This view was shared.
by Friedenberg & French. However, their conclusion were
based on experimental fractures fixed with spring-loaded
medullary nails and not with compression plates.

Bassett and Russi (1966) in experiments in vitro,
showed that mesenchymal cells under compression in the
presence of high oxygen tension might differentiate into
osteoblasts, whereas under tension, distraction, or low
oxygen concentration they might differentiate into
cartilagenous or fibrous tissue cells.

Anderson believe that the major advantages of the
ASIF technique are as follows: (i) Compression increases
the rigidity of fracture stabilization by impacting the
bone ends, (ii) the space between the fragments that must
be bridged by new bone is narrowed, & (iii) the developing
blood supply is protected by the rigid fixation. They found
that in adults the ASIF compression plate is a successful
method for obtaining union of acute displaced diaphysreal
fractures of the forearm and for restoring the best possible
function of the extremity. With the compression early active
motion is possible, thus helping to prevent muscle atrophy
and joint stiffness.

The better quality of implants together with
refinements in instrumentation and technique used for
internal fixation have improved the quality of rigid fixation.
In addition, the availability of aseptic techniques in modern
operation theatres have made surgical procedure safe.
In view of these, open reduction and internal fixation has
increasingly been the treatment of choice of most of the
surgeons.

The present study on closed displaced diaphyseal
fractures of both bones of the forearm in adults consist of
twenty patients. Most of the patients belong to age group
21 - 30 years (40%) (Table II). The mean age of the patients
was 28.25 years. All the patients were male. This was
perhaps due to the more vigorous life style of the younger
age groups, particularly the males. Burwell & Charnley
(1964) have reported, sex of the patient did not affect the
time taken for union or the union rate.

Fifty percent cases were urban and fifty percent
were rural (Table III) not in accordance with demographic
profile of India, according to which ratio should be 10:70.
This can be due to more dynamic mode of life in urban
population so more exposure to injury.

The level of fracture was mostly in upper 1/3rd
for radius (41.14%) and middle 1/3rd for ulna (70.90%)
(Table VI). Although different surgeons have pointed out
different levels of radius and ulna being prone to non-union
in the present series, following rigid internal fixation
the union rate was not found to be different for different
levels of fractures.
Non-dominant limb of the patient was involved in
63 percent of the cases (Table V). Those, with involvement
of non-dominant limb were found to return to daily activities
much earlier than ones with injury of dominant limb.

Over the years, it has been pointed out by almost
all surgeons that achieving satisfactory closed reduction
and its maintenance in plaster of paris cast is difficult
in displaced fractures of both bones of the forearm (Patrick,
1946; Knight & Purvis, 1949; Comic, 1957; Burwell & Charnley,
of 74.4 by Knight & Purvis (1949) and 40% by Bolton & Guinalan
(1952) were reported with conservative management of
fractures of both bones of forearm in adults. Most of other
surgeons have also reported unsatisfactory results with
conservative management with few exceptions like Evans (1945).
Sarmiento & Latta (1981) and Conolly (1981) have reported
good results with early functional bracing. Satisfactory
initial reduction, a pre-condition to obtaining good results
with functional bracing is not possible in most of the
displaced fractures of forearm bones in adults. The
technique of functional bracing is also not easy.

Following one unsatisfactory attempt at closed
reduction under anaesthesia, patients were treated by open
reduction and internal fixation in this study. In most of
the patients (85%) open reduction and internal fixation was
done within three weeks of injury (Table IX). Surgery was
delayed in 3 patients; out of these three, two were old
cases, one was 3½ month old mal-united monteggia fracture
dislocation and another was 9 month old non-union of both
bones of forearm, third patient had punctured wound over
fracture site which took four weeks to heal properly.

Controversies exist regarding the merit of delaying
internal fixation following injury. The concept that
delayed internal fixation promotes union received support
from Smith (1939), Charnley & Guindy (1961), Lam (1964)
and Hosecker and Kapta (1981). On the other hand, other
surgeons have pointed out that delay in open reduction and
internal fixation is less important if fixation is rigid
Lyritis & Co-workers (1983-84) have observed that in
fractures fixed rigidly time of operation did not have
statistically significant effect on healing process. In the
present study, where rigid fixation was used, the union rate
of fractures was not found to vary much.

The implants used for fixation included semitubular
plates (DCF) for use with 4.5 m.m. cortical screws. Semi-
tubular plates (SFS, DCF) for use with 3.5 m.m. cortical
screws to fix the fracture. In five patients fracture site
for radius was higher up, so square nail for radius and
compression plates for ulna with 4.3 m.m. cortical screws
were used (Table X). Using ASIF recommended techniques and
instrumentation, rigid fixation could be obtained in 34 (70%
out of twenty forearms (Table X). Neim & Pfeiffer (1983) have stated that fissure fractures may occur when 4.5 mm. screws are used, especially in slender bones. This problem can be overcome by using SFT, DCP with 3.5 mm. cortical screws. Madden & co-workers (1981-84) feel that at the moment the implant of choice for internal fixation of forearm bones is SFT, DCP with 3.8 mm. cortical screws. In the present study, it was found that technically it was much easier to fix the slender bones with SFT, DCP using 3.5 mm. cortical screws than with standard DCP using 4.5 mm. cortical screws. Also, the exposure required was less, thus decreasing the amount of dissection required and operating time.

In the present study, the plates were applied sub-periosteally with minimal stripping of periosteum. Sisk (1987) has recommended the same although Anderson (1984) expressed that plates should be applied extra-periosteally. Since there was no case of delayed union or non-union, in this study except due to implant failure, it is possible that sub-periosteal fixation does not affect the union rate.

Knight & Turvis (1949) had stated that in closing the wound deep fascia should be snugly sutured. This concept has changed since then. Anderson (1984) reported 3 cases of Volkmann's ischemic contracture in patients in whom deep fascia had been sutured. Closure of deep
fascia is not recommended (Sisk, 1987). In the present study, loose closure of deep fascia was done, keeping in view even if there is superficial infection in any case or few stitches gaps, without closing deep fascia, plate will be exposed particularly in case of ulna which is subcutaneous. Proper limb elevation and active finger exercises were encouraged post-operatively. Since none of the operated patients in this series developed any compartment syndrome, it can be said loose closure of deep fascia will not harm if there is proper post-operative elevation of limb is ensured.

In previous studies, there has been no mention of any universally accepted criteria for supplementary bone grafting. In this study, supplementary autogenous cancellous bone chips taken from the patients iliac crest were used for grafting in 3 patients. Two were old cases and one patient had significant amount of comminution and operation was also delayed due to time taken for healing of punctured wounds present over fracture site. The bone grafting did not affect the time taken for union of fracture. Anderson and Co-workers (1975) stated that no significant difference was found in rate of union of fractures fixed with or without bone grafting.

There have been varying views regarding post-operative plaster immobilization. Watson Jones (1955), Cove (1958) and Deburen (1967) recommended use of plaster
immobilisation till signs of union of fracture could be seen radiologically. Coyle (1957) and Hicks (1961) on the other hand seldom used post-operative plaster immobilisation. In the present study, post-operative external plaster immobilisation depended upon criteria used by Cruess (1973), Anderson (1986) and Siss (1987). The factors taken into consideration included patients co-operativeness and intelligence, amount of comminution, adequacy of fixation and whether or not supplementary bone grafting has been done. Based on this, one patient (5%) was not given any external immobilisation following stitch removal. Two patients were given plaster immobilisation upto 4 weeks (10%). Eleven patients were given plaster immobilisation upto 6 weeks (55%). Six patients (30%) were given plaster immobilisation for more than 6 weeks; out of these five patients were those in whom square nailing for radius was done, in effect compromising the adequacy of fixation since beginning.

As pointed out earlier by Sargent & Teigner (1965) and Grace & Eversmann Jr (1980), the patients in the present series also benefitted from comfort and convenience of absence of external plaster immobilisation for longer periods. They could perform everyday tasks which did not involve load bearing or excessive stress on the operated limb. The early return to work in case of patients with sedentary occupation and ability to find alternate employment benefitted all patients in whom external splint was removed early. Four out of twenty patients could return to patient
employment in less than 8 weeks after injury. Ten out of twenty (50%) did so within 8 - 12 weeks of injury. Two (10%) in whom fixation was not rigid return to work in 12 - 16 weeks of injury, in both of them square nailing was done for radius and compression plating for ulna. Four (20%) patients could return to work only after 16 weeks of injury. Two of these patients developed tourniquet palsy post-operatively and one patient in whom there was extensive comminution and square nailing was done for radius developed non-union of radius and another patient was in whom square nailing was done for radius and compression plating for ulna; later on plate bend and resulted in mal-union (Table XIV).

Different surgeons have given varying time of union of fractures. Knight & Parvis (1949) reported union times of 4.5 to 5 months in both bones forearm fractures treated by open reduction and internal fixation, whereas Anderson and co-workers (1975) reported union times of 7.4 weeks for radius of 7.3 weeks for ulna. In the present study, the time required for union varies with different types of implants used. On an average it was found to be 14.3 weeks with semitubular plates (DCP), 12 weeks with SFS, DCPs and 16.5 weeks with square nail for radius and compression plate for ulna (Table XIII).

Average time required for union was 14.33 weeks. Non-union was seen in two patients (10%) out of twenty.
cases (Table XIII). In one patient, with severe comminution of radius, square nailing was done for radius and compression plating for ulna. Due to inadequate fixation patient developed non-union of radius. In other patient with fracture shaft of radius semitubular plating was done with 4.5 mm cortical screws. Rigid fixation was seen at the time of operation and patient was mobilised after 6 weeks. Four weeks after mobilisation patient noticed pain in forearm around fracture site, on check radiograph some evidence of metal reaction was found.

The non-union rates reported by other surgeons following open reduction and internal fixation with compression plates vary viz. Sargent & Teipmar (1965) 0%, Dodge & Cody (1972) 0% in cases in whom primary internal fixation had been done in their series with 2 out of 28 delayed unions. Naiman & co-workers (1970) also had 0% non-union rates. Anderson and co-workers (1975) reported union rates of 97.9% for radius and 96.3% for ulna. They also stated that most of the failures were due to errors in surgical technique or poor implant quality.

Several post-operative complications were also encountered besides implant failures and non-union (Table XII). Superficial stitch infection occurred in three patients (15%). All the three patients with superficial infection were dressed alternate day with sterile dry bandage and infection subsided in one week.
Deep infection rate was '0' in this series. In all the three patients with superficial infection, union occurred normally and it did not affect the final outcome. Different infection rates reported by different surgeons are Dodge & Cady (1972) - 5.1%, Anderson & co-workers (1975) - 2.9%, Grace & Eversmann Jr. (1980) - 3.1% and Madden and co-workers (1983-86) - 5.4%. All these studies included patients with compound fractures in whom primary open reduction and internal fixation has been done. Anderson and co-workers (1975) reported that most of the infections in their series occurred in patients with closed fractures. Ferren (1979) in his experimental work showed that bone union can be achieved in the presence of maintained infection with staphylococcus aureus and reported union in 18 out of 19 such cases in sheep tibia.

Neurovascular complications which occurred included tourniquet palsy in two initial patients. One patient was 19 year old boy of both bones forearm fracture; in whom tourniquet was applied for one hour and thirty minutes, another patient was 55 year old male with Galeazzi fracture dislocation; in whom tourniquet was applied simply for one hour. Since the pneumatic tourniquet was not available. It was probably due to inadequate pressure alongwith more time in first patient and atherosclerotic vessels in another patient. All the three nerves i.e., median, ulnar and radial were involved. Both the patients recovered completely after physiotherapy. One about 3 weeks.
After these two incidents, use of tourniquet was stopped further and we did not encounter any neuro-vascular complication, nor excessive peri-operative bleeding. It was concluded in this study, since plating of forearm bones taken much more time than nailing; so tourniquet should not be applied and neither it is required, considering the complications involved. None of the patient in the present study developed posterior interosseous nerve palsy. The rate of post-operative nerve lesions reported by different surgeons are 10.2% by Dodge & Cody (1972), 2% by Anderson & co-workers (1975), 12.5% by Grace & Eversmann Jr. (1980), and 6.3% by Hadden & co-workers (1983-84). Hadden and co-workers (1983-84) reported significantly less post-operative nerve lesions with the use of 573, DCP with 3.5 m.m. cortical screws as compared to standard DCP with 4.5 m.m. cortical screws.

Radio-ulnar synostosis did not occurred in any patient in this series. Hadden & co-workers (1983-84) have noted the higher incidence of radio-ulnar synostosis in patients with head injury in whose forearms open reduction and internal fixation has been done. While reporting cross-union rate of 5.4% in their study, they have pointed out that cross-union rate is significantly less with the use of 573, DCP with 3.5 m.m. cortical screws as compared to standard DCP with 4.5 m.m. screws. Anderson and co-workers reported radio-ulnar synostosis rate of 1.2% in their series.
As there was little periosteal callus due to rigid fixation, there was difficulty in deciding as to when the fracture had united so that the patient could be permitted full load bearing and strenuous activity with the operated forearm. The criteria followed were the disappearance of fracture line and appearance of trabecular continuity as evident on the radiographs. Often, the size of plate made this assessment difficult and radiographs had to be taken in different views besides the routine antero-posterior and lateral views. Commenting on this, Unthoff (1980) had stated the need for the use of scientific criteria to determine the exact moment of fracture healing instead of trusting on empirical criteria.

As is obvious from the above discussion, complications in open reduction and internal fixation may lead to serious functional impairment. Fisher & Hambleton (1978) in a study on compression fixation of long bone fractures have pointed out that the surgeon using these methods should be well versed with them in order to have less complications and should be able to deal with the complications arising out of such treatment.

There are many reports on the results of treatment of displaced diaphyseal fractures of the forearm in adults. Different methods have been employed to treat these fractures. The results reported in different retrospective studies are
difficult to analyse and compare because of uncontrollable variables such as proportions of acute fractures, delayed unions and non-unions, the location and type of fractures, number of open and closed injuries and the extent of associated soft tissue and other injuries. The criteria used to evaluate the results differ so much that comparison are virtually impossible. The functional results are difficult to compare with those in other series in the absence of a standardised rating system for function of the upper extremity.

Two main reasons for performing open reduction and internal fixation in displaced diaphyseal fractures of both bones of forearm in adults are to achieve union and good function. Union and functions were therefore used as criteria to analyse results in the present study, based on the criteria used by Anderson and co-workers (1979) (Table I).

Functional results were excellent or satisfactory in 14 out of 20 (70%) of patients in whom open reduction and internal fixation had been done (Table IV). Three patients with inadequate fixation took long period to mobilize had unsatisfactory results. Two patients who developed tourniquet palsy and one in whom implant failure led to non-union of radius were considered as failure of treatment.
Functional results in different series have been reported using criteria which vary considerably. Acceptable results reported have been 66% by Burwell & Charnley (1964); 78% by Dodge & Cody (1972); 82% by Anderson & co-workers (1975); 80% by Grace & Kerssman Jr. (1980) and 80% by Hadden & co-workers (1983-84).

The role of supervised physiotherapy is of immense help to the patient in early recovery of good range of motion in joints of the operated limb and good muscle strength.

Extensive experimental works of Perren and co-workers (1969), Haavolainen and co-workers (1978) and Allgower and Spiegel (1979) on the concept of rigid internal fixation of fractures with early mobilisation of injured extremity have helped in shifting the trend towards open reduction and rigid internal fixation of fractures. Better techniques of anaesthesia, strictly aseptic operating environments and instruments, better implant quality and instrumentation for internal fixation and atraumatic techniques of surgery have led to low rates of complications and better functional results in fractures treated by open reductions and rigid internal fixation.

Although the present study has too small number of patients compared to the earlier mentioned studies, it has clearly shown that most
cases of displaced diaphyseal fractures of both bones of the forearm in adults have to be taken up for early open reduction and internal fixation.

Excellent functional results associated with a high union rate, were possible, in the present study due to availability of recommended manual and adequate instrumentation, strict adherence to the modern techniques of compression osteosynthesis and gentle tissue handling under aseptic operating conditions.