OBSERVATION OF APPLICATION OF BONE MARROW GRAFT FOR DELAYED AND NON UNION FRACTURES OF LONG BONE

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INTRODUCTION

Accidents are major epidemics of this century. Due to increase in movement of the people, absence of proper traffic regulation, poorly maintained vehicles, dilapidated roads and lack of proper training to drivers are causes for insult to skeletal system, especially of lond bones.

With the increase in fracture rate, complications of fractures have increased. Despite best of available treatements nearly 5% of them result in non- union and more than that in delayed union.

Delayed and non- union of fractures, a common problem, is quite annoying. Several methods such as bone grafting have been used to counter this problem.

Bones like tibia and humerus, are notoriously famous for delayed and non-union. For fracture shaft of humerus failure to control movement of gragments in the cast is responsible for above complications. Besides, gap may occur due to loss of bony fragments, soft tissue interposition, overriding and distraction due to weight of arm and plaster cast. While in fracture shaft of tibia union is delayed due to comparatively poor blood supply, and its compounding nature. Failure of implant due to infection retards osteogenesis at fracture site.

In this jet age the craze of modern surgery by internal fixation by Dynamic compression plate and screws, interlocking nail, external fixator and Ilizarov technique have tried to revolutionize the treatment of fractures with complications. Another technique of Osteogenesis by Electromagnetic stimulation has also been useful. But bone grafting is still the standard orthopaedic procedure for delayed and non- union of fractures. With the work

of Chitro in 1918 and Phemester in 1947 Onlay bone graft, Cancellous insert graft, sliding bone graft and their modification came into existence.

With the advent of high speed vehicles, weapons and bomb blast complicated fractures have become common. In conditions where there is some bone loss due to severe fracture or surgical resection, large amount of bone is required to replace these defects. Enormous amount of donor sites are not available especially in pediatric and Osteoporosis patients. To overcome this problem frozen calf bone by Kingman in 1960 and Freeze dried and deproteinized calf bone of Burwell 1966 were used with unsatisfactory results : Kiel ‘bone by Salama 1993 was even not very successful despite tall claims.

Advances in cellular and molecular biology have made the understanding of bone healing clear. Experimental studies demonstrated the osteogenic potential of bone marrow cells for treatment of delayed and non-union of fractures. It was observed that bone marrow contains mesenchymal cells that has the ability to differentiate into osteblasts which can form new bone. These cells can be obtained by aspirating bone marrow from iliac crest. Thus bone marrow grafting at fracture site proved to be a simple method of providing cellular elements at the fracture site to enhance osteogenesis. Despite this fact its use had been much less in clinical practice.

Mc Graw and Harbin (1934) were the first to exhibit the osteogenic activity of bone marrow. Burwell (1964) demonstrated that bone graft which stimulates healing in a case of non- union depends on the cellular activity of graft particularly of the bone marrow. He further suggestedthat bone graft containing marrow were more osteogenic. Tiedeman et al. (1991). Connolly et

al. (1991), Sim R. et al. 1993 suggest use of autologous bone marrow graft in delayed and non- union Herring P. et al (1997) demonstrated usefulness of bone marrow graft in patients with pseudoarthrosis.

With a simple needle prick, the exact location of fracture site can be easily approached without much bleeding in the area and bone marrow can be thus, transplanted with accuracy and resultant benefit. Patients can go home the same day or the next day. This is economical and patient compliance is maximum.

MATERIALS

AND

METHODS

MATERIAL AND METHOD

This work has been done in the Ortho Centre, Club Road, Arrah (Bihar) 802301

Subject :

Patients with delayed and un-united fracture of long bones especially of humerus, tibia, Radius, Ulna and femur were selected for this study.

Most of them were treated and followed up as outdoor patients. But some of them were hospitalized as per the requirements. When this procedure was combined with internal fixation and in some patients in whom post operative observation was required, such cases were admitted for some time in the hospital.

Material Used :

Materials used specifically for bone marrow harvesting and its instillation are mentioned below. Some patients needed internal fixation detailed of description of their implants and surgical methods used in them are not mentioned in this study. During bone marrow transplant, following antiseptic solutions viz. Cetavelon, Betadine and surgical spirit, pre-anesthetic agent like atropine, diazepam, for twin and anesthetic agents like ketamine, 2% xylocaine were used. Ciprofloxacin tabs., were commonly used to combat infection. Multivitamines and minerals were used as supportive drugs.

Instruments :

Puncture needles with stiletto used for bone marrow aspiration varied in gauzes (from 14-16). Klima needles with A stern around 4.5cm were used for iliac crest and Salah needle with a longer stem were used for frcture sites. Disposable syringes (20ml. capacity) were used to aspirate bone-marrow.

This project includes study of rate and quality of union after percutaneous autogenously bone marrow grafting in patients with :-

1. Fractures ended up in delayed union after conservative treatment.
2. Fractures with internal or external fixation yet resulting into non-union.

Pre-operative preparation :

Cleanliness on the parts of patient deserved priority. They are instructed to attend with clean cloths and after having properly washed with antiseptic soaps etc.

Donor Site :

Iliac crest was selected as most common donor site. This was prepared with antiseptic swabbing soaked in Cetavelon and Betadine plus surgical spirit.

Recipient Site :

Recipient sites were aseptically prepared similarly. Where the limbs were in plaster, windows of sufficient size were made. When larger areas were required the whole plaster was removed. Aseptic preparation of skin was done. After making window, plaster ends were made covered with sterile gauzefrom all sides. This prevented dropping of plaster particles inside the operative area. Then drapping was done with sterile towels.

Pre-medication :

One ampoule of atropine was injected to the patient intramuscularly as pre-anaesthetic medication about half an hour before the procedure.

In majority of the patients, this procedure were performed under short acting General Anaesthesia such as Calmpose and Ketamine. Patients who

were not fit for General Anesthesia, we used 2% Xylocaine as local anesthetic agent along with For twin and Calm pose intravenously.

Oerative Details :

The position of patient was supine with a sand bag placed under. Gluteal region to stabilize the back and make the donor site prominent. This greatly facilitated the proper entry of needle through the iliac crest. Thus the chances of damage to pelvic organs was minimized. Similarly, another sand bag was kept under the recipient site to stabilize the part. In case of humerus, Radius and Uln the upper limb was kept on the arm support or side- table for easier and better access to the site of bone marrow grafting.

Procedure Proper :

Under short acting general anesthesia, donor as well as recipient sites were draped aseptically.

The fracture site was localized with the help of radiogramme and by gross measurement from fixed anatomical points. With this method, we found it easier to locate the fracture sites. We preferred to negotiate two Salah needles at different angle near the fracture site. After this, we introduced a marrow needle (Klima type) with stiletto in position in the iliac crest.

Bone marrow needle (Klima) was inserted about five centimeters behind the anterior superior iliac spine through the middle of the widest portion of the iliac crest. After the needle got inserted upto the guard, it was readjusted at the higher point and again rotatory thrust was applied. The procedure was repeated till 2-3 cms. Of the needle was into the ilium. This is essential for harvesting adequate bone marrow from this area. The stilectto was then removed from the needle and a 20ml. non heparinished disposable

syringes was attached to it. Plastic syringes were used for aspiration for two distinct advantages over glass syringes, Chances of breakage of the nozzle is less, and aspiration of marrow is much easier due to better vaccum effect in tight plunger syringe system of the olastic syringes.

Bone marrow was aspirated by repeated retraction of the plunger of the syring with simultaneous rotation of the needle. This avoids back filling by venous blood. Adequate amount of marrow was aspirated in similar fashion. In our study 20 cc. of marrow was aspirated for the cases of humerus, tibia, both bone of forearm and about 30cc. to 40cc. for femur and larger defects in humerus and tibia. Since this procedure can be done quickly, heparin is not required. Both punctured wounds at donor and recipient sites were sealed with cotton swab soaked in Tincture Benzoin solution.

Finally, either repair of the window was done or fresh POP cast was applied to immobilize the limb. The general condition of patients was assessed and kept under observation till the patient recovered safely from anaesthesia. This procedure was repeated two to three times at the intervals of 3 to 4 weeks in each case depending on the progress of union which was assessed both clinically as well as radio logically.

Post-operative Management :

Post-operatively oral antibiotics, analgesics and multivitamin were given for 5 days.

Follow-up- It was done both clinically as well as radiologically every 4^{th} week for 3 to 4 times.

Clinical and radiological parameters were used to evaluate and assess the bone healing as below.

OUT COME

1. Bony tenderness
2. Abnormal mobility
3. Bony tenderness
   - (a) Marked '++"
   - (b) Mild M '+"
   - (c) Absent '-'
4. Abnormal mobility
   - (a) Fairly present '++'
   - (b) Just present '+'
   - (c) Absent '-'

Clinical union was graded as

- (i) Poor
- (ii) Fair
- (iii) Good

(B) **Radiological Evaluation**

- (i) Visible fracture gap
- (ii) Arinount of Callus
- (iii) Visible fracture gap
  - (a) Full fracture line visible '++++'
  - (b) Fracture line partly visible '+++'
  - (c) Fracture line obliterating '++'
  - (d) Fracture line obliterated '+'
- (iv) Amount of Callus
  - (a) Exuberant callus formation '++++'

(b) Marked callus formation ‘+++’

(c) Moderate callus formation ‘++’

(d) Slight callus formation ‘+’

OBSERVATION

The present series of "FURTHER STUDY OF OBSERVATION ON PERCUTANEOUS AUTOGENOUS BONE MARROW GRAFTING IN DELAYED AND UN-UNITED FRACTURES OF LONG BONES" was conducted in the Ortho centre, Club Road, Arrah (Bihar).

Table-I

Showing sex distribution

Sex	Total no. of patients	Percentage
Male	23	96
Female	1	4

Above table is showing the total number of cases according to sex distribution. Of 24 patients included in our study 23 were males and only 1 female. This may be attributed in females to more indoor activity, less of outing and hence less being prone to accidents.

Table-II

Age incidence

Age Group	No. of patients
below 35 years	8
35 years and above	16

In our study the age of patient varied from 6 years to 54 years with a mean of 37 years. The above table indicates higher incidence of delayed and non-union of fractures in aged.

Table- III

Showing total number of follow up cases

Total no. of patients	No. of patients presently under treatment	No. of patients lost in follow up	Total no. of patients included and observed
24	1	3	20

The above table reveals that out of 24 patients, 3 cases were lost during follow up. 1 case is presently under treatment. Only 20 patients were finally included and observed during study.

Table-IV

Incidence of Bone involved

Involved bone	No. of cases
Tibia	9
Femur	
Shaft	4
Neck	1
Humerus	4
Radius & Jlna	2

The above table reveals number of each bone in whom bone marrow treatement was done in Tibia 9, femur 4+1, humerus 4 and radius & Ulna 2 cases.

Table-V

Showing type of fracture

Type	No. of cases
Compount	11
Simple	9

Above table shows incidence of cases of 9 closed and 11 open fractures.

Table – VI

Site of Fractures

Site of fracture	Tibia	Femur	Humerus	Radius & Ulna
Lower third	7	1	1	0
Middle third	1	3	3	1
Upper third	1	0	0	1
Neck	-	1	0	0

The incidence of delayed and non- union were found to be more in mid portion of femur and humerus and lower portion of tibia.

Table-VII

Duration of Injury

Age of injury	No. of cases
1 year and more	3
6 months to 1 year	17

The above table shows time interval elapsed since injury and bone marrow grafting. 17 cases whose injury varied from 6 to 12 months and 3 cases whose injury were more than 1 year old.

Table –VIII

Mode of treatment given prior to Bone Marrow grafting

Modality of treatment	**Tibia**	**Humerus**	**Radius & Ulna**	**Femur**
P.O.P. Cast	7	3	0	1
External Fixator	2			1
Dynamic compression plate	0	1	0	-
Kuntscher nail	0	0	0	2
Forearm square nail	0	0	2	-
Kirchner wire	0			1

The above table indicates the mode of immobilization of fracture.

Out of 9 fractures of Tibia, 7 were immobilized conservatively in cast and 2 were by External fixator.

The fracture shaft of femur was immobilized by Kuntscher nail in 2 cases, External fixator in 1 case and POP cast in 1 case. The fracture neck of femur after Mc. Murrey's Osteotomy was immobilized by K-wire and hip spica.

Of 4 cases of fracture shaft of humerus 3 were immobilized in POP cast and one by DCP plate.

The 2 forearm bone fractures were immobilized by forearm square nail.

Table-IX

Complication during treatment with Bone marrow grafting

FeverAge Group	0
Infection	0
Pain at donor site	4
Neuropraxia	0

Above table indicates the complications encountered during this procedure. There was no complain of fever or infection. Four patients complained of pain at donor site for 2-3 days which was relieved by mild analgesics.

Table-X

Number of Instillation of Bone Marrow

No. of bone marrow grafting	**No. of cases**	**Percentage**
One time	4	20
Two times	8	40
Three Times	8	40

The above table shows number of times the bone marrow injection was given at the interval of four weeks.

Table –XI

Clinical Evaluation of Fracture site at Four Weeks post grafting

No. of patients	Bony tenderness	Abnormal mobility	Clinical union
1	+	-	Poor
2	-	-	Fair
3	+	+	Poor
4	-	-	Good
5	-	+	Fair
6	+	-	Fair
7	-	-	Good
8	+	+	Poor
9	+	+	Poor
10	+	+	Poor
11	+	+	Poor
12	+	-	Fair
13	-	-	Good
14	-	-	Good
15	+	-	Fair
16	-	+	Fair
17	+	-	Fair
18	+	+	Poor
19	+	-	Poor
20	+	+	Poor

Bony Tenderness	**Abnormal mobility**	**Clinical union**
Marked “++”	Fairly present “++”	Poor
Mild “+”	Just present “+”	Fair
Absent “-“	Absent “-“	Good

Table –XII

Radiological Evaluation at four weeks

No. of patients	Visible fracture gap	Amount of callus	Radiological union
1	+++	+	Fair
2	+	+	Fair
3	++++	+	Poor
4	+	+	Fair
5	+	+	Fair
6	+++	+	Fair
7	+	+++	Good
8	+++	+	Fair
9	+++	+	Poor
10	+++	+	Fair
11	+++	+	Poor
12	+++	+	Fair
13	+	+	Good
14	+	+	Fair
15	++++	+	Poor
16	+	+	Fair
17	+++	+	Fair
18	++++	+	Poor
19	+++	+	Poor
20	+++	+	Poor

Visible fracture gap	**Amount of callus**	**Radiological Union**
Fracture line obliterated '+'	Exub. Callus '++++'	Good
Fracture line obliterating '++'	Marked Callus '+++'	Fair
Fracture line partly visible '+++"	Moderate Callus '++'	Poor
Whole fracture line visible '++++"	Slight callus '="	

Table –XIII

Clinical Evaluation at eight weeks

No. of patients	Bony tenderness	Abnormal mobility	Clinical union
1	-	-	Good
2	-	-	Good
3	+	+	Poor
4	-	-	Good
5	-	-	Good
6	-	-	Fair
7	-	-	Good
8	-	-	Good
9	+	+	Fair
10	-	-	Good
11	-	+	Fair
12	-	-	Good
13	-	-	Good
14	-	-	Good
15	+	-	Fair
16	-	+	Fair
17	-	-	Good
18	+	-	Poor
19	+	-	Fair
20	+	-	Fair

Bony tenderness	**Abnormal mobility**	**Clinical union**
Marked ‘++’	Fairly present ‘++”	Poor
Mild ‘+’	Just present ‘+’	Fair
Absent ‘-‘	Absent ‘-“	Good

Table –XIV

Rediological Evaluation at Eight weeks

No. of patients	Visible fracture gap	Amount of callus	Radiological union
1	+	+++	Good
2	+	+++	Good
3	+++	+	Poor
4	+	+	Good
5	+	+	Good
6	+	+	Good
7	+	+++	Good
8	+	+	Good
9	+	+	Good
10	+	+	Good
11	+	+	Good
12	+	+++	Good
13	+	+	Good
14	+	+++	Good
15	+	+	Good
16	+	+	Good
17	+	+++	Good
18	+++	+	Poor
19	+	+	Fair
20	+	+	Fair

Visible fracture gap	Amount of callus	Radiological Union
Fracture line obliterated '+'	Exub. Callus '++++'	Good
Fracture line obliterating '++'	Marked Callus '+++'	Fair
Fracture line partly visible '+++"	Moderate Callus '++'	Poor
Whole fracture line visible '++++"	Slight callus '+"	

Table –XVII

Clinical Evaluation at twelve weeks

No. of patients	Bony Tenderness	Abnormal Mobility	Clinical Union
1	-	-	Good
2	-	-	Good
3	-	+	Poor
4	-	-	Good
5	-	-	Good
6	-	-	Good
7	-	-	Good
8	-	-	Good
9	-	-	Good
10	-	-	Good
11	-	-	Good
12	-	-	Good
13	-	-	Good
14	-	-	Good
15	-	-	Good
16	-	-	Good
17	-	-	Good
18	+	-	Poor
19	-	-	Good
20	-	-	Good

Bony tenderness	Abnormal mobility	Clinical union
Marked '++'	**Fairly present '++'**	**Poor**
Mild '+'	**Just present '+'**	**Fair**
Absent '-'	**Absent '-'**	**Good**

Table –XVII

Radiological Evaluation after twelve weeks

No. of patients	Visible fracture gap	Amount of callus	Radiological union
1	+	+++	Good
2	+	+++	Good
3	+++	+	Poor
4	+	+	Good
5	+	+++	Good
6	+	+	Good
7	+	+++	Good
8	+	+	Good
9	+	+	Good
10	+	+	Good
11	+	+	Good
12	+	+	Good
13	+	+	Good
14	+	+++	Good
15	+	+++	Good
16	+	+	Good
17	+	+	Good
18	+++	+	Poor
19	+	+++	Good
20	+	+++	Good

Visible fracture gap	**Amount of callus**	**Radiological Union**
Fracture line obliterated '+'	Exub. Callus '++++'	Good
Fracture line obliterating '++'	Marked Callus '+++'	Fair
Fracture line partly visible '+++"	Moderate Callus '++'	Poor
Whole fracture line visible '++++"	Slight callus '+"	

Above mentioned tables display the clinical and radiological union at 12 weeks. We observed that good clinical and radiological unions were achieved

in all cases except case no.-3 and 18. Case number 3 was that of gunshot injury of thigh causing comminution and bone loss of femur. It was initially stabilized by skeletal traction followed by POP slab after bone marrow grafting.

Another case was that of fracture shaft of humerus treated by internal fixation by DCP plate without bone grafting and proper compression. This resulted due to distraction at fracture site.

Table –XIII

Union

Duration	No. of cases	Percentage
Within 12 weeks	18	90%
Not united	2	10%

Radiological Union was graded as

(i) Good

(ii) Fair

(iii) Poor

Our study continued and observation made accordingly.

Discussion

The incidence of fracture has increased with the advent of speedy vehicles and as such due to increase in mobility of population from one place to another. Thus the incidence of its complication like non-union and delayed union has also enhanced. This has always been a point to ponder for the orthopaedic surgeons.

This series is an attempt to evolve a useful technique for daunting problems of delayed and non-union by evaluating the osteogenic potentials of authologous bone- marrow grafting done percutaneously in these cases. Its results are comparable with the series of work published in various other medical journals and literatures.

In this series whole bone marrow instead of centrifuged one was used. The bone marrow was not heparinized as it was used immediately. Cannolly (1989) used centrifuged heparinized bone marrow. The fracture site was located radiologically. Gross measurements were made from the fixed bony points to install the aspirated bone marrow into it. In cases it was injected near the fracture site it percolated to the desired places. However, instillation under image intensifier should be preferably used as advocated by Cannolly and Healey. Accuracy could be ascertained to the greatest extent by that method.

The age of patient varied from 6 to 54 years. The mean age being 37 years. In this study the number of cases of delayed or non- union of tibia, femur, humerus and forearm boneswere 9,4+1,4 and 2 respectively (Table IV). Kienerman (1966) studied the fracture shaft of humerus and suggested that this bone is vulnerable to delayed and non- union because of improper Mobilization, soft tissue interposition and bone loss. Likewise the fracture of

shaft of tibia is also notorious for delayed and non- union because of poor bood supply, bone loss due to high velocity injuries and distraction. (Fracture and Joint injury, Watson jones, 1983).

Fractures of shaft of log bones were categorized into upper middle and lower 1/3rd in order to evaluate any difference in healing patterns varying as per as the the site of fracture (Table- VI).

In our study of tibial fractures included one case of upper third, one case of middle third and the remaining 7 were of lower third. It was observed that fracture of lower third of tibia is more prone to delayed and non- union because of its poor blood supply by end arteries which break after injury. However, Nicoll (1964) suggested that the number of cases of delayed and non- union were equal in all segments. In our study also the incidence of delayed and non- union were much in lower third (7 out of 9).

9 Out of 18 cases of delayed and non- union were originally compound fractures, (mostly type III as per Gustillo- Anderson classification (Table V). Similar observation has been found to be done by others also N.K. Garg in his series found 10 out of 20 cases compound in nature, (mostly Type-I) Connolly found 19 of 20 tibial cases as open fractures (mostly type III). Our observation tallied with others in cases of compound fractures.

The time interval between injury and bone marrow grafting was divide in to two categories. Cases between 6 months to 1 year were numbered 17 whereras 3 patients reported after one year (Table-VII). In the study of cannolly et al. the time interval from injury to bone grafting ranged from 7 to 36 months with median being 18 months.

Along with percutaneous authologous bone marrow grafting the fracture was immobilized either by Plaster of Paris cast or any Internal or External fixation device. Without adequate immobilization the newly formed callus breaks. In this series 11 cases were immobilized by POP cast and 9 by internal or external fixation (Table- VIII).

The most common problem encountered after aspiration from iliac crest was pain for 2 or 3 days. The pain was not persistent and this was further prevented by using alternate iliac crests. None had any operative or Post operative Post-operative problems. The only set back encountered was failure to achieve union in 2 case due to large bony defect and lack of proper Mobilization. The marrow itself is not an osteoconductive agent and so it cannot fill up large spaces. This was observed also by Connolly.

We observed that some of the cases (4=20%) needed single bone marrow grafting 8 cases needed this procedure twice while 8 cases needed it thrice. We used 20 cc of whole bone marrow (Table- X).

As an average all cases were assessed at 4 week intervals and reviewed whether subsequent bone marrow instillation was required or not. It was found that single bone marrow instillation was useful in cases of delayed with ongoing osteogenic process. In some cases where bone formation was insufficient after a single instillation a second injection was required. A third injection was required in few cases.

On clinical evaluation at the interval of 8 weeks after bone marrow injection marked tenderness was absent in 17 cases. No case had obnormal mobility at the fracture site. 18 patients had fair clinical union at 8 weeks.

In clinical evaluation after 12 weeks of bone marrow injection, bony tenderness was absent in all the cases except 2. Abnormal mobility was present in only case of failure, the other was fixed by DCP plate.

Radiological assessment at 12 weeks showed fracture line just obliterated with moderate to marked callus formation.

In 2 cases scanty amount of callus formed (case no. 3 and 18). This occurred because of firearm injury with severe comminution and bone loss in case 3 and bone gap in case 18. The bone marrow does not have a osteoconductive effect may be the reason behind this. Connolly had also observed this fact that the grafted bone marrow does not fill up the large spaces.

We observed that in our cases time taken for complete union varied from 2 to 6 months 90% of our cases united which is comparable with the result of other workers. The above mentioned workers achieved union in 80 to 100% cases within 3 to 6 months (mean 3.5 months)

This method of percutaneous bone marrow grafting plays a definite role in aling of fractures in cases of delayed and non- union. It has a lower incidence of morbidity, short hospital stay and low cost of therapy when compared with open bone grafting.

Thus having seen considerable advantages, we recommend this modality of treatment for delayed and non- union of fractures of long bones. This is a quite useful method which involves less of manpower, material, sophisticated operating theatres and highly skilled surgeons. This can be done as OPD procedure by trained orthopaedic surgeon even in the remotest parts of our country as well as other developing countries. This can benefit

larger population with affordable expenditures. This defies the old saying of “Beggars are not choosers”. Besides, in our observation we have noticed that many desparate cases who have already tried many methods without success have been the happiest individuals by seeing their dreams of union many failures coming to be true after this technique was adopted.

SUMMARY & CONCLUSION

In our study, 20 cases of delayed and un- united fractures of long bones were given autogenous bone- marrow grafting percutaneously at the fracture site.

Of 20 patients, 19 were males. The age of patients varied from 6 years to 54 years with a mean of 37 years.

The long bones involved were, tibia & fibula, femur, humerus or radius & ulna either in their upper, middle or lower thirds, Most of the fractures were initially compounding in nature.

Most of the patients reported after 6 months of injury. But 3 patients reported after a gap of 1 year following the initial assault. The fracture was immobilized either by POP cast, IM nail, k-wire, External fixator or DCP plate percutaneous bone marrow grafting was done at the fracture site at the interval interval of 4 weeks, without much compolications. It was either given once, twice or thrice depending upon the progress of union as judged both clinically and radiologically.

In our study, the fracture united in 18 cases (90%) within 12 weeks. The other 2 cases (10%) failed to unite even after bone marrow grafting done thrice.

Based on the achievement of result of this series and the series of other pioneers, I highly recommend the use of percutaneous authogenous bone marrow grafting at the fracture site to achieve union in the cases of delayed and un- united fractures which were either treated conservatively or operatively. This method being simple, cheap and not requiring hospital stay, can be done by orthopaedic surgeons without any additional training even at

the peripheral hospitals. This avoids a major second surgical procedure. Hope this work will go a long way to alleviate the sufferings of humanity.

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Patt and Maloney (1972) observed that reticular cells in the endosteum are osteoblast precursors and circulatory bone marrow stem cells have a predilection for colonizations in a osseous environment.

Friedenstein (1973) described bone marrow stroma as a mixture of mesenchymal cells. Some of whom are pre-osteoblasts or differentiated bone cells in bone marrow stroma while others are less differentiated but highly responsive to an osteo inductive matrix.

Mimmons and Lesker (1975) painfully counted the number of marrow cells before transplantation and noted that the amount of early osteogenesis was proportional to the number of marrow cells.

Salama and Weisman (1978) used bone marrow with hydrogen peroxide macerated ki el bone as a composite graft successfully.

Lindoholm and Urist (1980) demonstrated that one matric induced both bone marrow and muscle tissue derived from mesenchymal type cells to differentiate into new bone.

Jackson et al (1981) – Expermental and clinical studies proposed that because of capability of self replication and generating differentiated cartilage and bone, the stromal osteogenic cell may perform the function of a skeletal. Tissue stem cells.

DECLARATION

To,

The Administrator,

Dear Sir,

The dissertation “Observation of application of bone marrow grafts for delayed and non- union fractures of long bone” represents valid work and that neither dissertation nor one with substantially with similar contant under the authorship of Dr. Kanhaya Jee Singh has been published or is being considered for publication else where. The authorship as placed in the dissertation in final.

Thanking you,

Sincerely Your’s

(Dr. Kanhaya Jee Singh)