ORIGINAL ARTICLE

Bone Transport in the Management of Fractures of the Tibia

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Summary

A review was carried out in 21 cases of bone transport in the tibia done between May 1995 and December 1997. These were done for the treatment of compound (Grade IIIB) fractures with extensive bone and soft tissue loss and in infective non-unions of the tibia using the Ilizarov technique and ring fixator. In 5 cases, 2 or 3 additional procedures were needed such as tendo achilles (TA) lengthening, bone grafting, revision of construct or revision of scar at the docking site.

Average resection of infected bone was 5.2 cms in the infective non-union group and average bone and soft tissue loss was 8 cms in the compound Grade IIIB fracture group.
The defect was bridged and regenerate bone occurred in all the cases except one. Union was achieved in all the cases although 10 needed bone grafting. Infection was eradicated in all the cases. Limb length discrepancy was corrected in all the cases except three. Mean duration of treatment was 12 months.

The result was judged excellent in 7, good in 7, fair in 5 and poor in 2 cases.

Key Words : Ilizarov, Bone transport, Compound fractures

Introduction

The treatment of compound Grade IIIB fractures of the tibia (Gustillo's classification) with extensive bone and soft tissue loss and the treatment of infective non-union have always posed a difficult and challenging problem to the orthopaedic surgeon.

Acute compound Grade III B fractures with bone loss are conventionally treated initially by wound debridement and free or local flaps to obtain soft tissue cover, followed later by vascularised fibular grafts [1,2,3,4] or massive allografts to restore bone loss. The infective non-unions are conventionally treated by repeated wound debridement to eradicate infection and by repeated bone grafting to obtain union [5,6,7].

Stabilization of these fractures are usually done with a unilateral external fixator as the infection usually precludes the use of a plate or nail hence union is seldom achieved. We used the Ilizarov technique of bone transport to treat these cases. The Ilizarov Technique of bone transport has been practiced in Russia since World War II by Gavriil Ilizarov [8,9]. Europeans have been using this technique since the early 80's and it was introduced in America in the mid 80's [8,9]. In Malaysia,

this technique has been in use since the early 90's, but it has not gained much popularity. This is a technique where a bone defect (Fig. Ia) is bridged by a percutenous osteotomy called corticotomy done either proximally or distally to create a segment of bone (transport segment). This segment is gradually advanced at a rate of 1 mm a day with regenerate bone (Fig. Ib) forming behind at the osteotomy gap [8,9].

The Ilizarov technique can be used in a variety of conditions but it is most useful in restoring bone loss following trauma or following resection of osteomyelitic or tumour bone. With the use of hinges it can also treat malunions and complex or congenital deformities. This is the only technique to date that can address infection, bone loss, non-union, deformity and length simultaneously [8,9].

Objective

The aim of this study is to report the results of the authors' early experience in Malaysia using the Ilizarov's methods for the treatment of Grade IIIB fractures with extensive bone and soft tissue loss and in infective non-unions of the tibia.

Materials and Methods

Twenty-one consecutive cases seen between May 1995 and December 1997 in Hospital Seremban were reviewed to determine the outcome of this new technique. Nine were infective non-unions and eleven were open Grade IIIB and one Grade IIIA fracture of the tibia with extensive bone and soft tissue loss. All these cases were treated initially by wound debridement and A.O. Tubular external fixators.

The nine infective non-unions are described in Table I. All were treated by resection of the osteomyelitic and necrotic bone. Mean length of resection was 5.2cms. Of the twelve acute fractures with bone loss, one, with open Grade IIIA fracture had a bone loss of 12 cms. The other 11 Grade IIIB fractures with bone and soft tissue loss are described in Table II. Loss of skin and fascia was less than 6cms in 5 cases and more than 6cms in six cases respectively. Of this six cases, where soft tissue loss was more than 6cms, 2 had loss of little and fourth toes as well. The longest bone and soft tissue loss was 18 cms and the shortest was 3 cms. Average bone and soft tissue loss was 8 cms. Site of the fracture sustained are listed in Table III.

Table I
Extent of bone resection in 9 patients with infective non-union of the tibia

No.	Original fracture	Original bone loss	Length of bone resection
7cases	Compound Grade IIIA	Nil	3cms - 3cases 5cms - 3cases 6cms - 1case
2cases	Compound Grade IIIB	3cms hemicircumferential bone loss	7cms - 1case 10cms -1case

The patients age ranged from 12 years to 62 years. Six were between 12 to 20 years, nine were between 21 to 40 years and six were over 40 years of age. Average age was 34 years.

The time interval between injury to application of ring fixator in compound fractures was within one month in 8 cases and over one month in 4 cases whilst in the infective non-union group, the time interval was between 6 months to 1 year in six cases, over 1 year in one case and over 2 years in two cases.

We used stainless steel rings in 16 cases and aluminum alloy rings in 5 cases. Sixteen cases had the standard 5 ring construct, 2 rings each proximally and distally and one transport ring. Two cases had only 4 rings. The rings were connected to each other by 4 threaded rods. Surgery was begun by first resecting the osteomyelitic segments at the fracture site together with a thorough debridement of the bone and soft tissue. Next, Kirschner wire of 1.8mm diameter each were passed through the upper and lower end of the tibia, parallel to the joint line. This was confirmed by X-ray. The fixator was then applied over the leg and the wires were fixed by bolts and nuts to the rings at a tension of 110 kg. The wires were transfixed through the bone usually at an angle of 145° to 35° to each other. The alignment was then confirmed by X-ray before carrying out the

Table II
Extent of bone and soft tissue loss in 11 patients with acute Grade IIIB fractures of the tibia

Soft tissue injury	Skin and fascia	Skin, fascia and tibialis anterior	Skin, fascia, tibialis anterio and extensor digitorum longus
	7 cases	2 cases	2 cases
Bone loss	3-5cms - 5cases 6cms - 1case 7cms - 1case	7cms - 1case 10cms - 1case	15cms - 1case 18cms - 1case

Table III
Level of tibia fractures

Site of Fractures	Number of Cases
Upper third	5
Middle third	6
Lower third	10

corticotomy to ensure a perfect docking. Corticotomy (osteotomy of bone whilst preserving as much periosteum and endosteum as possible) was performed through a 2 cm incision anteriorly over the skin, fascia and periosteum. With a curved mosquito haemostat, the periosteum and skin was lifted off from the bone both over the medial and lateral cortices.

With a 3.2 mm drill bit a few holes were drilled around the circumference of the bone. The bone was then osteotomised with a 10 mm osteotome through the medial and lateral cortices extending to the posteromedial and posterolateral corners. Bifocal corticotomy was done in 3 cases, double proximal in 1 case and both distal and proximal in 2 cases. Single corticotomy was done in 18 cases of which 9 were proximal and 9 were distal. The interconnecting threaded rods were removed and the rings were rotated and the bone was cracked by osteoclasis.

Distraction was commenced after a period of 10 days at a rate of 3/4 mm a day. Post operatively, routine use of antibiotic (cefuroxime or fusidic acid in cases of MRSA) was continued for two weeks. Patients were started on non-weight bearing crutches from the 3rd day. Partial weight bearing was started when regenerate bone was seen radiologically. Full weight bearing was commenced when regenerate bone had consolidated (clinically). Union was assessed clinically by disconnecting the threaded rods at the docking side. If union was confirmed, then the fixator was removed and Patella Tendon Bearing (PTB) cast was applied and patient was advised to continue full weight bearing for another 1 month. If it was still mobile at the docking site, then the rods were reconnected and patient was reviewed again after 6 weeks. If it was still the same, then bone grafting was done within the next 6 weeks.

Results

Of the 13 cases of soft tissue and bone loss, 6 cases with extensive bone and soft tissue loss needed revision of scar at the docking site (at the time of docking) due to invagination of skin and fibrous tissue between the fragments. Revision surgery of scar entailed excision of the invaginated skin and fibrous tissue with bone grafting.

The skin edges were apposed at the docking site. It was not possible to suture the skin as the skin was adherent to the underlying bone. One patient had a foot frame applied during the primary procedure because of foot drop. One patient had an additional ring applied subsequently when the transport segment had a fracture line and the distraction was taking place at the fracture line instead of at the proximal corticotomy site. Hence an additional ring was applied and a distal corticotomy was done.

Table IV
Complications occurring during bone transport treatment

Type of Complications	Numbers of Cases	Notes
Pin Tract Infection	5 cases	All resolved with antibiotics & dressing
Wound Infection	2 cases	All resolved with antibiotics & dressing
Deep Vein Thrombosis	2 cases	Both developed lymphoedema
Stiffness of ankle	5 cases	1 with ankle arthrodesis Range of Motion (ROM) -0° 4 cases ROM-0-10°
Equinus	3 cases	Corrected with TA lengthening. ROM 0°
Stiffness of Knee	4 cases	ROM 0-90° - 1 case ROM 0 - 100°- 3 cases
Varus deformity < 7 degrees	1 case	
Valgus deformity <10 degrees	2 cases	
Shortening - 2 cm	2 cases	Acceptable
- 4 cm	1 cases	Patient choice
Non-union	10 cases	Bone grafting had to be done.

In 2 patients during the course of distraction, the proximal fragment angulated posteriorly because the proximal fragment was less than 3 cms and hence had only one ring. In these two cases the angulation was corrected acutely under general anaesthesia and stabilised with two additional half pins in addition to the two tension wires.

Complications

Two patients developed lymphoedema (Fig 2a & 2b) and eventually needed amputation of the leg. In the remaining 19 cases the complications were not severe and did not affect the outcome as listed in Table IV.

Bone grafting was done in 10 patients who developed non union at the docking site. One patient refused bone grafting however the fracture united on its own one year after removal of the fixator. In one patient, bone grafting was done twice at the corticotomy site and at the docking site. Fibula osteotomy and acute docking was done in 3 patients to achieve union.

Equinus occurred in 3 patients. To correct equinus, TA lengthening was done and PTB cast was applied in 1 patient. TA lengthening with foot-frame application was done to correct equinus gradually by distraction and compression in two other patients.

Ankle arthrodesis was done in one patient who had bone loss distally including articular cartilage loss. This patient and the other 3 who had TA lengthening had bone grafting done at the same time.

Outcome

The duration of treatment was between 6 months to 1 year in 15 cases, more than 1 year in 2 cases and more than 2 years in 4 cases. Mean duration of treatment was 12 months (similar to other published results[10,11,12,13,14,15,16]). Duration of treatment is the period between application of fixator to full weight bearing after removal of the fixator and PTB casts.

The results are divided into bone results and functional results according to the classification of the Association for the Study and Application of the Method of

Table V
Four outcome categories for results of bone transport of the tibia

Poor	Restoration of functional limb not achieved and amputation is eventually needed.
Fair	a) Duration of treatment >2 years ± complications*OR b) Duration of treatment <2 years with >2 complications.
Good	Duration of treatment <2 years, only 1 complication.
Excellent	Duration of treatment < 2 years, no complication.

**Complications being: shortening, infection, deformity ,stiffness of ankle and knee.*

(The ankle or knee was considered stiff if range of motion of the joint was not full)

The results as based on the above criteria are shown in Table VI. The result was Poor in 2 cases, Fair in 5 cases, Good in 7 cases and Excellent in 7 cases.

Ilizarov[8]. The criteria we used to determine the results in this study is simplified, practical and yet more comprehensive as we took into consideration the duration of treatment in addition to length , deformity, infection and function i.e.: knee and ankle stiffness. The remaining functional criteria were excluded as we felt it was too subjective.

Our outcome criteria was divided into four categories given in Table V.

Discussion

This review has shown that in cases of compound Grade IIIB fractures with bone loss, plastic surgery is not necessary to obtain soft tissue cover unlike other published reports, Dendrinos[10] reported 28 patients, 10 were Grade IIIB fractures which were treated by plastic surgery. Dror Paley[11] reported a series of 28 patients. Of those with Grade IIIB fractures all required plastic surgery. Sugar[17] had 20 cases, 6 cases were treated by plastic surgery. Lenoble[18] had 12 cases of which 2 needed gastrocnemius flap.

Application of primary shortening with secondary limb lengthening for open injuries associated with combined bone and skin defects has been reported by several surgeons[19] using the Ilizarov technique. This can be done provided the bone loss is not more than 5 cms.

Grade IIIB fractures are conventionally treated by obtaining soft tissue cover with soleus, gastrocnemius or fasciocutaneous flaps. But if they are associated with extensive bone loss of more than 6 cms then some of these cases will need amputation as expertise for vascularised fibular graft is not easily available. The Ilizarov technique of bone transport is certainly a good alternative to vascularised tissue transfer. Weiland[1] did 37 vascularised tissue transfers of which seven failed and four of these needed amputation. Of the 30 that were successful, six had persistent and recurrent infection. In his other series,[2] out of 41 cases, 4 failed and required amputation. Watson[3] was not successful with free fibular grafts in acute fractures of the tibia.

In our series, 10 cases needed bone grafting. This is much higher than other published results. None of Cattaneo's[15] cases needed bone grafting. Green[16], reported seventeen cases, 5 cases needed bone grafting. Dror Paley[11] reported 28 patients, 6 cases needed bone grafting. Dendrinos[10] had a nonunion rate of 11%.

Polyzois[12] had a non-union rate of 10%. In our series the non-union rate is higher as none of our patients had plastic surgery to obtain soft tissue cover. Six of our cases with extensive soft tissue and bone loss had skin and fibrous tissue interposition at the docking site, this certainly contributed to the non-union at the docking site.

In the infective non-union group, osteomyelitis was eradicated in all the cases (similar to other published results[10,11,12,13,15,16]). We did not have any fractures or angulation of regenerate bone similar to other published results [10,11,12,13,15,16]. Out of 21 cases only one did not regenerate bone as the patient did not understand how to carry out the distraction protocol. Sometimes it may take up to 6 months before regenerate bone can be seen radiologically.

Table VI
Outcome of treatment with bone transport using our criteria

Outcome	Number of patients	Case description	Results
Poor	2 cases	1 case of fracture with 15 cm bone & soft tissue loss.	Above knee amputation
		1 cases of Infective non union with 10 cm bone loss. Had co-existing foot-drop & Ipsilateral brachial plexus injury.	Below knee amputation Both had deep vein thrombosis and lymphoedema(Fig. 2a & 2b)
Fair	5 cases (24%)	1 case - infective non-union.	Took >2 years to eradicate infection & achieve union.
		2 cases - infective non-union.	(1 developed equinus & 1 had shortening of 2 cms). Took > 2 years for consolidation of fracture & regenerate bone.
		2 cases of fracture.	1 - shortening of 2 cms with stiffness of ankle & a varus deformity of 7 degrees. 1- shortening of 4 cms (Patient's choice).
Good	7 cases (33.3%)		2 - valgus of 10 degrees. 2- ankle stiffness. 3- knee stiffness
Excellent	7 cases (33.3%)		

Stability of the construct should not be compromised. Standard 5 ring construct should be used where ever possible. If only one ring can be applied proximally or distally, then this should be augmented with extra tension wires or shanz pins. Pin tract infection is a minor problem as it can be easily treated with antibiotics and dressings.

Complications like deep vein thrombosis, equinus, knee and ankle stiffness can be avoided by early ambulation, joint mobilisation and partial weight bearing. The major factor hindering this is the weight of the fixator, hence our patients are not able to return to work while on treatment. This was unlike Dendrinos[10] series and Dror Paley[11] series, where 82% and 60% respectively were able to return to work while on treatment.

This technique can also be quite demanding for the surgeon as it requires meticulous planning and pre-assembly of the construct a day before surgery. Care and commitment is also required in the post-operative period as the patient has to be followed up at frequent intervals, at least once fortnightly in order to detect complications early. In 4 of our cases the duration of treatment was more than 2 years.

The other disadvantage is the fact that repeated procedures may be needed as some patients may develop complications. In our series, the 5 cases who had multiple secondary procedures were those done early on in the series. Probably some of these could have been avoided if we had had enough experience. As with other procedures this procedure has a learning curve.

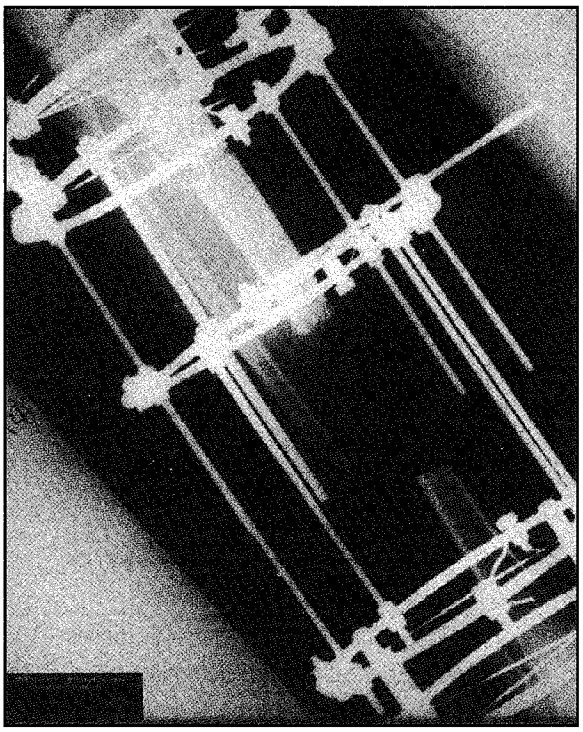

Fig. 1a : Showing extent of bone loss,proximal corticotomy and transport segment.

Fig. 1b : Showing consolidation of regenerate bone and union at docking site. The final outcome.

Fig. 2a : A case of lymphoedema which resulted in an above knee amputation.

Fig. 2b : A case of lymphoedema which resulted in a below knee amputation.

Two patients had a poor outcome and needed amputation. One patient had extensive bone and soft tissue loss of more than 15 cms. He developed deep vein thrombosis and lymphoedema and eventually needed amputation(Fig. 2a). The other patient was a case of severe infective non-union in whom 10 cms of osteomyelitic bone was resected. He had ipsilateral brachial plexus injury making rehabilitation difficult hence he developed deep vein thrombosis with lymphoedema and eventually needed an amputation (Fig. 2b). This patient was also mentally subnormal and was therefore a poor choice for this technique.

Limb length was restored in all the cases except three. In 2 cases the shortening was 2 cms. In the other it was 4 cms. This patient had initial bone loss of 12 cms, when the transport segment had docked and internal length restored, he was supposed to continue with the distraction to restore external length but the patient was reluctant and refused as he lacked patience.

Conclusion

This review confirms that the Ilizarov method is effective in restoring bone loss and soft tissue cover in compound Grade IIIB fractures and that plastic reconstructive surgery is not required since the bone transported carries with it the overlying skin although this will be at the expense of requiring bone grafting.

Our review also confirms the findings of other authors [10,11,12,13,15,16] that in infective non-unions the Ilizarov technique is the best method of eradicating infection and achieving union. Hipocrates said of osteomyelitis "One should especially avoid such cases if one has reasonable excuse for the risk is great and rewards are few". With the advent of the Ilizarov technique, this no longer holds good today. Our result overall compares favourably with those of others, although our result represents the learning experience in Malaysia with distraction osteogenesis.

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