Combined Bone Transportation and Lengthening Techniques in the Management of Traumatic Bone Defects

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Abstract: Aim: Dealing with traumatic large bone defects by Ilizarove methods with distraction osteogenesis is one of the main effective methods to deal with this type of common injuries. Combined bone transportation and lengthening is a technique theoretically offer decrease apparatus time, increase limp lengthening range and easier ability for adjustment. **Material and Methods:** The study carried out during 2019 to 2020. It was multicenter study at the Orthopedic Department of Helwan University Hospital, Police Hospital and finally El Helal hospital. 17 cases were included. Subjects were admitted for bone transport for massive bone defect. **Results:** The results showed that the apparatus modification have good results and have better outcome or equivalent to other studies using classical bone transport technique. **Conclusion**: The apparatus modification to merge bone transport with bone shortening techniques to deal with bone defects give comparable results to classical method. This study supports bone transport modification as a good alternative to classical method of massive traumatic bone defects of the tibia. Future areas of investigation to compare both techniques in comparative studies and also compare both types of modification.

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1. Introduction

Non-union of long bones with segmental defect is a major problem. It usually follows high energy trauma leading to open fractures with soft tissue damage and may be further complicated by infection. Segmental bone loss may be due to initial injury, secondary to debridement or produced by post-traumatic osteomyelitis that needs resection of the necrotic bone segment for treatment [(1)].

Several different surgical treatment options have been proposed, including bone grafting, free tissue transfer, antibiotic cement, and Ilizarove methods. There are some limitations in bone grafting, such as the size of bone defects, donor site morbidity, and extended graft incorporation time. Although free tissue transfer is suitable for the treatment of large bone and soft tissue loss, it is a technically demanding surgery, and it is usually associated with stress fractures and nonunion [(2)].

Ilizarove methods can overcome all these difficulties and address coexisting problems simultaneously. Progressive bone histogenesis following corticotomy and bone transport help in filling bone gaps eradicating infection and promoting fracture union [(2)]. Radical debridement is the key step to control bone infection [(3)].

Distraction osteogenesis is a process capable of generating viable osseous tissue by gradual separation of osteotomized bone edges. This technique was originally described by Ilizarov in Russia [(4)]. Osteotomy is made in one of the major fragments. Slow gradual transport of the middle fragment at a rate of 1 mm per day is started after 7 days. This slow distraction causes recruitment of progenitor cells from the endosteum at the osteotomy site [(1)].

An alternative technique for Posttraumatic segmental bone defects (PTSBDs) involves acute limb shortening with subsequent lengthening of the limb. This technique has the theoretic advantage of faster healing of the traumatic fracture because it does not require waiting until docking is achieved to begin healing. Another advantage is that shortening assists with closure of soft-tissue defects. However, acute shortening of large defects may cause soft-tissue redundancy and swelling [(5)].

Combined bone transportation and lengthening is new technique starting with bone transport technique till the docking site is engaged followed by changing apparatus and fibular osteotomy to continue lengthening till the normal length is reached with theoretical advantage to increase length range in the same time decrease docking site healing period. This new technique also theoretically offers decrease apparatus time and increase limp lengthening option.

2. Patients and Methods

Settings:

The study carried out during 2019 to 2020. It was multicenter study at the Orthopedic Department of Helwan University Hospital, Police Hospital and finally El Helal hospital. 17 cases of tibial nonunion with bone and soft tissue defect. All patients were males. The mode of trauma was a road traffic accident in 10 cases, motor car accident 5 cases and gunshot injuries in 2 cases. The patients were chosen to participate in the study after obtaining a verbal consent.

Selection Criteria:

Inclusion criteria:

- Age group: adults older than 18 years.
- Sex: both sexes.
- Traumatic bone defect.

Table 1: Pre-operative assessment results in our study sample

Case	Age	sex	Smoking	Side	cause of injury	Time between original injury & ilizarov (months)	Paley	Gustillo	Previous OP	Infection PreOP	Type of soft tissue defect
1	22	M	NO	Lt	MCA	24	B3	III B	1- Ex Fix 2- Masquelet	Yes 4A	skin loss
2	26	M	No	Lt	RTA	6	B1	III B	1- ilizarov	No	Adherent scar of trauma
3	36	M	NO	Rt	MCA	6	B3	II	1- Ex fixator	Yes 1A	Adherent scar of trauma
4	43	M	Yes	Lt	RTA	8.2	B1	III B	1- ilizarov	No	Adherent scar of trauma
5	23	M	No	Rt	MCA	5.5	B1	III B	1- Ex Fix - ORIF fibula fasciotomy	Yes 1A	skin loss
6	27	M	No	Rt	Gunshot	9.5	B3	III A	1- Ex Fix 2- ilizarov	No	skin loss
7	39	M	No	Lt	RTA	8.6	B1	III B	1- ilizarov	No	skin loss
8	39	M	Yes	Lt	RTA	7.8	B1	II	1- ilizarov	No	Adherent scar of trauma
9	25	M	Yes	Rt	RTA	22	B1	Closed	1- Double PS + BG 2- ilizarov	No	Adherent scar of Plate
10	25	M	No	Rt	Gunshot	10	B3	III A	1- Ex Fix + BG	No	Adherent scar of BG surg
11	32	M	No	Lt	MCA	22	B3	Closed	1- plate	No	Adherent scar of Plate
12	30	M	No	Rt	RTA	5.3	B3	III B	1- Ex Fix	No	Skin lossa
13	52	M	No	Lt	RTA	24	B3	III B	1- Ex Fix 2- ilizarov	No	Skin lossa
14	34	M	No	Rt	RTA	6.3	B3	III B	1- Ex Fix	No	Skin loss
15	29	M	No	Rt	RTA	5.6	B3	III B	1- Ex Fix	No	Skin loss
16	36	M	No	Lt	MCA	6	B3	III A	1-plate	No	Adherent scar of trauma
17	57	M	Yes	Rt	RTA	9	B3	III B	1- Ex Fix	No	Skin lossa

Exclusion criteria:

- Associated vascular injury.
- Insensate foot.
- Pathological fractures.
- Nonunion without large bone defects.

Full history which includes details of the primary insult and previous interventions. Examination of shortening, deformity, neurovascular deficiency and skin condition and all were documented.

Radiological assessment of the fracture based on Paley's classification [6]. Patients with infected non-union were further classified according Cierny and Mader osteomyelitis staging system [7]. Post traumatic soft tissue assessment according to Gastilo classification of open injureies[8]. Finally soft tissue defects classified to adherent scar, infected sinus or skin loss.

All patients were consented about associated complications before reconstructive surgery. Full information about expected time and different surgeries is detailed for every single patient. In all patient Length is maintained over an in long rods classical bone transport apparatus Fig (1) or on modified apparatus with two segments rods one for bone transport and another rod for further lengthening Fig (2). The decision regarding the amount of bone resection was based on the presence of healthy bleeding bone ends.

Technique of the operation:

Subperiosteal corticotomy transverse osteotomy at metaphyseal area was performed for transport. Radiological assessment of alignment is undertaken to ensure adequate docking. Classical bone transport is changed for small rods apparatus Fig (3). Incisions at docking site are performed. Resection of infected or non-viable bone and soft tissue. If necessary, the frame is adjusted under general anaesthetic to correct malalignment. Iliac crest graft may be applied in the docking site nonunion after excision of any interposed soft tissue. Fibular osteotomy is done to allow more lengthening (bone lengthening on double rods could be started at this stage). Compression at the fracture site is maintained till union, distraction at the corticotomy site is continued until limb length equality is achieved.

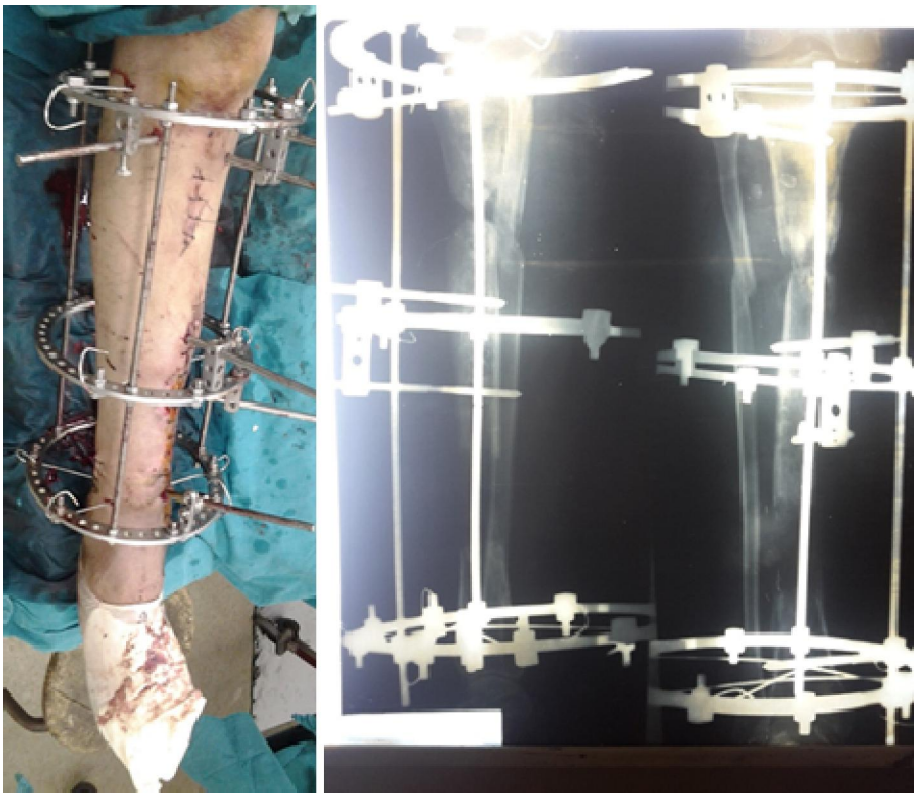


Figure 1: classical bone transport apparatus

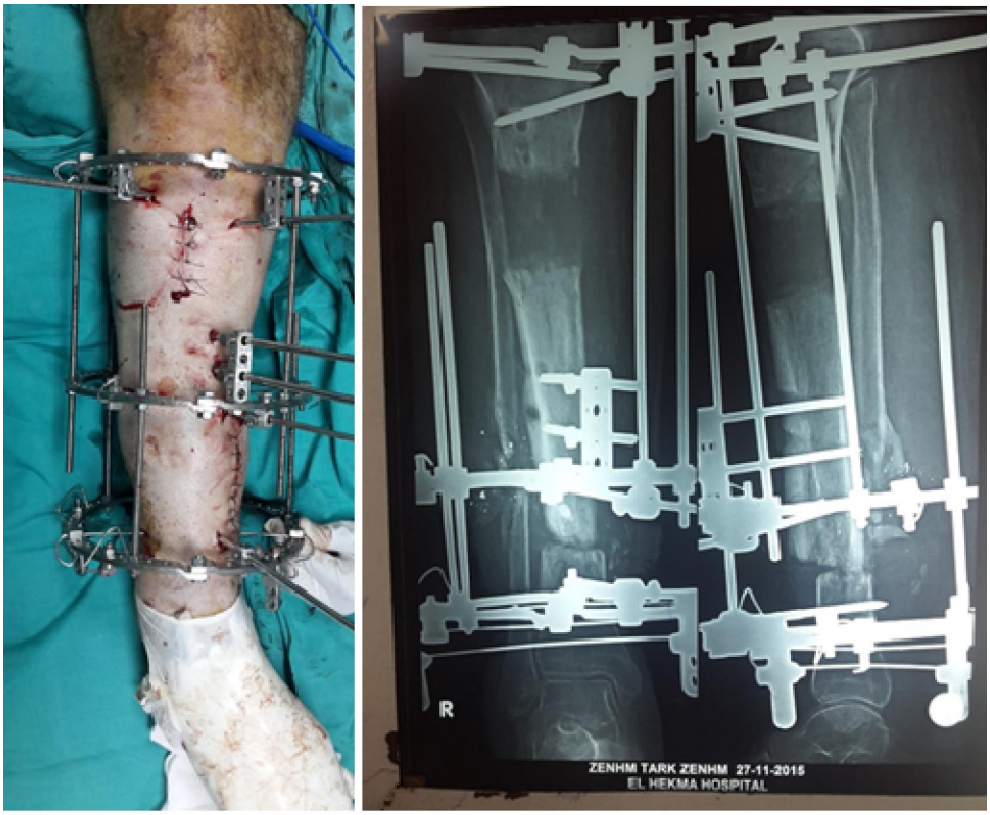


Figure 3: Classical bone transport is changed for small rods apparatus.

Postoperative follow up started with range of motion and weight bearing as tolerated. Distraction rate of l mm a day in four time separated by 6 hours between day 5 and 7. Pin site care and hygiene were taught to all patients. Followed up every 2 weeks and distraction were adjusted based on the radiological consolidation of the regenerate.

Completion of union was examined by the disappearance of pain, tenderness and mobility between bone segments at docking and corticotomy site. Radiological healing can be confirmed by bony consolidation in three out of four cortices. After complete dynamization of the rings removal of the frame can be done. Cast was applied for a period of three weeks with gradual mobilization to full weight bearing. After removal of the cast, the patient was allowed gradually to walk without assistance.

Statistical Analysis:

The data will be collected and statistically analyzed. Description of quantitative variable will be done as mean and standard deviation, and qualitative data as frequency. Chi-square test will be used to compare the groups as regard qualitative variable. Student test will be used to compare two groups as regard quantitative variable in parametric data. The results will be considered significant (S) with $P<0.05$ & highly significant (HS) with $P< 0.01$. Analysis of data will be done using IBMSPSS software (statistical program for social science version 26).

Ethical consideration:

Agreement for this study was obtained from the hospital's ethical committee, and an informed oral and written consent were taken from all patients included in the study prior surgery after a very clear explanation of both procedures, adequate providing of information about the study necessities, purpose, and dangers.

3. Results

All the cases in our study had tibial bone defect and also had at least one or two operative intervention before starting bone transportation management. Four patients in our cases were smokers. The mean time between the initial injury and our intervention was 10.1 months.

Preoperative osteomyelitis was classified according to Cierny and Mader classification. One Patient was A4 and tow patients were A1.

Intraoperative debridement and gap measuring till reaching bleeding edges. Average of the bone gaps was 6.9 cm. The average distraction distance 7.6

Union was achieved in all cases and one cases need bone graft at the docking site but finally union was achieved.

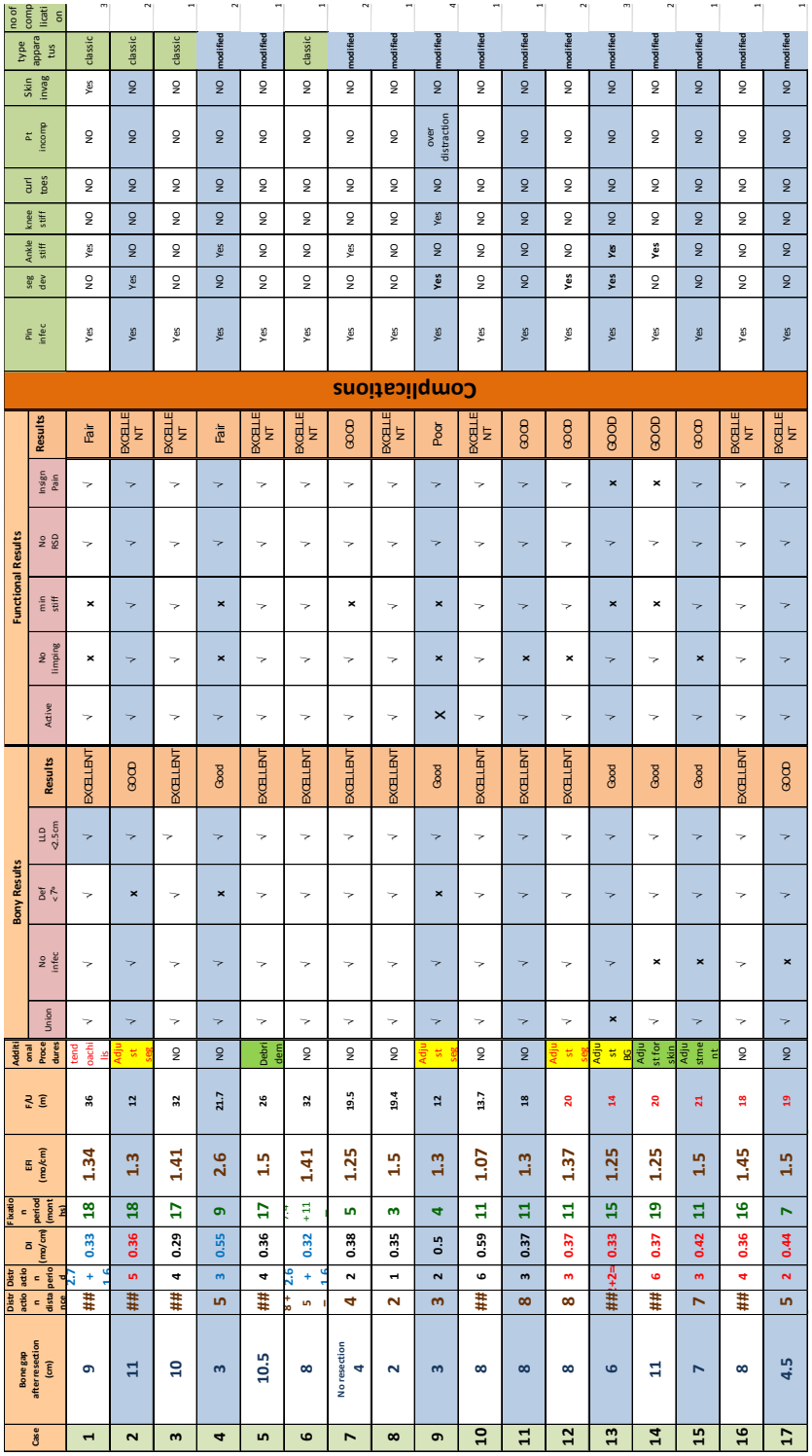
The mean Frame time removal average was 10.9 months.

The average of external fixation index (time taken for union, per centimeter) in our study was 1.6. The mean number of complications per patient was 1.7 (range 1 to 4). All patients had at least one pin site infection managed by the local care and systemic antibiotics. Deviation of the transported bone segment was seen in four cases (23%), over distraction and patient noncompliance was seen in one case (6%). Ankle stiffness is presented in five cases (29%) in.

Additional procedures were required eight patients in the bone transport group. These included adjustments of the frame and/or insertion of wires to realign the transport segment, debridement of infection and also, bone grafting at the docking site which was only in one case (less than 5 percent). Complications reported in our cases were successfully managed during the course of treatment and did not affect the final results (Table 3).

Using Association for the Study and Application of the Method of Ilizarov Classification, the bony results were excellent in 10 cases (58%), good in 7 cases (41%), The functional results were excellent in 8 cases (47%) of cases, good in 6 cases (35%) and fair 2 cases and poor in only one case.

Table 2: Table of results and complication



Case	Bone gap after resection (cm)	Distraction note	Distraction period (d)	Dl (mo/cm)	Fixation period (months)	EFI (mo/cm)	F/U (m)	Additional Procedures	Bony Results: Union	No infec	Def <7°	LLD <2.5cm	Results	Functional Results: Active	No limping	min stiff	No RSD	Insign Pain	Results	Complications: Pin infec	seg dev	Ankle stiff	knee stiff	curl toes	Pt incomp	Skin invag	type apparatus	no of complication
1	9	##	2.7 + 1.6	0.33	18	1.34	36	tendoachilis	√	√	√	√	EXCELLENT	√	x	x	√	√	Fair	Yes	NO	Yes	NO	NO	NO	Yes	classic	3
2	11	##	5	0.36	18	1.3	12	Adjust seg	√	√	x	√	GOOD	√	√	√	√	√	EXCELLENT	Yes	Yes	NO	NO	NO	NO	NO	classic	2
3	10	##	4	0.29	17	1.41	32	NO	√	√	√	√	EXCELLENT	√	√	√	√	√	EXCELLENT	Yes	NO	Yes	NO	NO	NO	NO	classic	1
4	3	5	3	0.55	9	2.6	21.7	NO	√	√	x	√	Good	√	x	x	√	√	Fair	Yes	NO	Yes	Yes	NO	NO	NO	modified	2
5	10.5	##	4	0.36	17	1.5	26	Debridem	√	√	√	√	EXCELLENT	√	√	√	√	√	EXCELLENT	Yes	NO	NO	NO	NO	NO	NO	modified	1
6	8	8 + 5	2.6 + 1.6	0.32	F/U +11 m	1.41	32	NO	√	√	√	√	EXCELLENT	√	√	√	√	√	EXCELLENT	Yes	NO	NO	NO	NO	NO	NO	classic	1
7	No resection 4	4	2	0.38	5	1.25	19.5	NO	√	√	√	√	EXCELLENT	√	√	x	√	√	GOOD	Yes	NO	Yes	NO	NO	NO	NO	modified	2
8	2	2	1	0.35	3	1.5	19.4	NO	√	√	√	√	EXCELLENT	√	√	√	√	√	EXCELLENT	Yes	NO	NO	NO	NO	NO	NO	modified	1
9	3	3	2	0.5	4	1.3	12	Adjust seg	√	√	x	√	Good	X	x	x	√	√	Poor	Yes	Yes	NO	Yes	NO	over distraction	NO	modified	4
10	8	##	6	0.59	11	1.07	13.7	NO	√	√	√	√	EXCELLENT	√	√	√	√	√	EXCELLENT	Yes	NO	NO	NO	NO	NO	NO	modified	1
11	8	8	3	0.37	11	1.3	18	NO	√	√	√	√	EXCELLENT	√	x	√	√	√	GOOD	Yes	NO	NO	NO	NO	NO	NO	modified	1
12	8	8	3	0.37	11	1.37	20	Adjust seg	√	√	√	√	EXCELLENT	√	x	√	√	√	GOOD	Yes	Yes	NO	NO	NO	NO	NO	modified	2
13	6	##+2=	6	0.33	15	1.25	14	Adjust BG	x	√	√	√	Good	√	√	x	√	x	GOOD	Yes	Yes	Yes	NO	NO	NO	NO	modified	3
14	11	##	6	0.37	19	1.25	20	Adjust for skin	√	x	√	√	Good	√	√	x	√	x	GOOD	Yes	NO	Yes	NO	NO	NO	NO	modified	2
15	7	7	3	0.42	11	1.5	21	Adjustment	√	x	√	√	Good	√	x	√	√	√	GOOD	Yes	NO	NO	NO	NO	NO	NO	modified	1
16	8	##	4	0.36	16	1.45	18	NO	√	√	√	√	EXCELLENT	√	√	√	√	√	EXCELLENT	Yes	NO	NO	NO	NO	NO	NO	modified	1
17	4.5	5	2	0.44	7	1.5	19	NO	√	x	√	√	GOOD	√	√	√	√	√	EXCELLENT	Yes	NO	NO	NO	NO	NO	NO	modified	1

4. Discussion

This study was designed to evaluate the new transport technique combined modification and compare it to other classical bone transport paper. In the present study, the mean participant's age was 34.

Posttraumatic bone defects can be successfully treated using the bone transport technique. The

technique addresses the bone defect, soft-tissue loss, infection, deformity, and leg-length discrepancy simultaneously. [9]

In this study, we tried to focus on merging the acute shortening apparatus techniques with bone transport by making of modification by shortening the rods around docking site and regenerate site and adding fibular osteotomy and continue distraction after docking.

The 1st prove that we can deal with LLD easier because you can increase distraction more than the gap defect after fibular osteotomy and that is obvious with our results as the average of the bone gaps was 6.9 cm while the average distraction distance 7.6.

This also give us an indicator that the paper managed large bone defects in comparison to other papers like the paper by Anis and Edward the mean length of regenerate gain was 5.7 cm (range,0.8–20.4 cm). [9]

The mean Frame time removal average in our paper was 10.1 months which is lesser than the systemic review by Peng and Quinan with the mean external fixation time was 10.69 months in the patients. [10]

The average of external fixation index (time taken for union, per centimeter) in our study was 1.4 (less than 42 days) which is comparable to 45 days in the study by Julian and kris [11]

The mean number of complications per patient was 1.7 (range 1 to 4) which is not a big difference than earlier anise and Edward study results the mean number of complications per patient was 2.1 (1.1 minor complications and 1.0 major complication). [9]

ASAMI (Association for the Study and Application of the Method of Ilizarov) Classification the bony results were excellent in 10 cases (58%), good in 7 cases (41%), The functional results were excellent in 8 cases (47%) of cases, good in 6 cases (35%) and fair 2 cases and poor (12%) in only one case.

Table 3: Comparison of bony results of bone transport with those in literature.

S. No.	*Name Of Author*	*Year*	*Excellent (%)*	*Good (%)*	*Fair (%)*	*Poor (%)*
1	Maini et al [12]	2000	70	10	0	20
2	Patil et al [13]	2006	42	34	10	14
3	Farmanullah et al [14]	2007	57	21	14	8
4	Chaddha et al [15]	2010	52	4	0	44
5	Shahid et al [16]	2013	83	17	0	0
6	Yin et al [3]	2014	67	23	7	3
7	Sahu et al [17]	2016	50	7	2	1
8	Rohilla et al [18]	2016	54.5	37	0	8.5
9	**Our study**	**2019**	**58**	**41**	**0**	**0**

Table 4: Comparison of functional results of bone transport with those in literature

S. No.	*Name Of Author*	*Year*	*Excellent (%)*	*Good (%)*	*Fair (%)*	*Poor (%)*
1	Maini et al [12]	2000	27	40	10	23
2	Patil et al [13]	2006	44	44	6	6
3	Farmanullah et al [14]	2007	57	31	7	5
4	Chaddha et al [15]	2010	24	36	16	24
5	Shahid et al [16]	2013	50	33	0	17
6	Yin et al [3]	2014	40	43	17	0
7	Sahu et al [17]	2016	45	10	3	2
8	Rohilla et al [18]	2016	40	54.3	2.85	2.85
9	**Our study**	**2017**	**47**	**35**	**10**	**6**

The success rate of our study was comparable to other series which ranged from 83% to 100% [12-18].

Conclusion

The apparatus modification to merge bone transport with bone shortening techniques to deal with bone defects give comparable results to classical method. This study supports bone transport modification as a good alternative to classical method of massive traumatic bone defects of the tibia.

Future areas of investigation to compare both techniques in comparative studies and also compare both types of modification.

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