Retraction of transporting bone segment during Ilizarov bone transport

xiaofei han (yinqudong@sina.com)
Wuxi Hand Surgery Hospital
Yunhong Ma
Wuxi Hand Surgery Hospital
Qudong Yin
Wuxi Hand Surgery Hospital

Research article

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Abstract

Background: Retraction of transporting bone segment (TBS) may occur when fixator of TBS is removed before complete mineralization of the distraction callus and union of the docking site. However, there are few reports on the causes and influencing factors of the retraction of TBS.

Methods: The clinical data of 37 cases with tibial bone defect treated by Ilizarov bone transport were analyzed retrospectively, in whom the fixator of TBS was removed before maturing of mineralization of the distraction callus and union of the docking site. Bivariate correlation was used to analyze relationship between retraction distance of TBS and factors including age, gender, disease course, length of bone defect, times of operation, size of TBS, transport distance, timing and time interval of removal of TBS fixator. Risk factors with significant level were further identified using multivariate linear regression.

Results: Bivariate correlation analysis showed that the timing of removal was negatively correlated with the retraction distance while the time interval, transport distance were positively correlated with the transport distance（all $p<0.05$); the age, gender, disease course, length of bone defect, size of TBS and times of operation were not correlated with the transport distance（$p>0.05$). Multivariate linear regression analysis of the 3 risk factors showed that the timing of removal and time interval were the main risk factors for the retraction distance ($p<0.05$), of which, the timing of removal had the greatest impact, followed by the time interval, but the transport distance was not a main risk factor for the retraction distance ($p>0.05$).

Conclusion: The TBS is subjected to distraction force from all the adherent soft tissues during Ilizarov bone transport, which has elastic properties and can make a retraction of TBS when its fixator is removed before complete mineralization of the distraction callus and union of the docking site. The timing of removal and the time interval are key factors influencing the retraction of TBS.

1. Background

Callus distraction (distraction osteogenesis) by Ilizarov's method has been an effective technique to reconstruct large bone defects and correct discrepancies of limbs[1-3]. Removal of external fixator is usually performed after complete mineralization of the distraction callus and union of the docking site in conventional Ilizarov bone transport. However, traditional Ilizarov bone transport presented high rates of delayed union and nonunion of the docking site and pin-track infection or loosening, inconvenience for rehabilitation and nursing, and psychological disorder induced by long-term external fixation[3-6]. These complications and defects have become the bottleneck for the development of this technique. Therefore, how to reduce complications and defects has become a clinical research topic. Recently, some scholars [7-9] reported improved Ilizarov bone transport with less complications, in which the external fixator was removed in advance when the docking site are closing or showing difficulty in healing and then plate or intramedullary nail was used as a relay internal fixation. However, 1-2 weeks or longer is need for the pin-track to heal before implantation of relay internal fixation. During the period between removal of external fixator and implantation of relay internal fixation, retraction of transporting bone segment (TBS) may occur even if plaster cast was used. The retraction of TBS has adverse effect on the healing of the docking site. Previous literatures paid more attention to the bone union and complications in distraction osteogenesis, rarely reported the causes and influencing factors of retraction of TBS[10-12]. Understanding retraction phenomenon of TBS can help to take appropriate measures to avoid adverse effect or complications. Therefore, the clinical data of 37 patients with removal of TBS fixator in advance during bone transport process in our hospital from January 2009 to December 2018 were retrospectively analyzed to identify the causes and risk factors of the retraction of TBS.

2. Methods

2.1 Inclusion and exclusion criteria

Inclusion criteria: Patients with tibial defect were treated by Ilizarov bone transport; TBS fixator or total external fixator was removed before maturing of mineralization of the distraction callus and union of the docking site. Exclusion criteria: Patients with incomplete radiographic data were excluded. This study was approved by the ethics committee of Wuxi no.9 People's Hospital and Shuyang People's Hospital, and written informed consents were obtained from all participants.

2.2 Patients

Between January 2009 and December 2018, 37 cases were included in the study who were traumatic fractures with tibial bone defect. Before bone transport, all patients with bone defect were fixed with ring or single arm external fixator, among them, 5 cases were simultaneously treated by shortening of the affected limb. There were twenty-three males and fourteen females, ranging in age from 15 to 71 years with an average age of 39.95 years.

2.3 Observation indexes

Retraction distance: the retraction length examined by radiographic evaluation before and after removal of TBS fixator.

The course: the days from traumatic bone defect to bone transport.

Times of operation: the number of operations performed on the patients before bone transport.

Timing of removal of TBS fixator: from the beginning of bone transport to the removal of TBS fixator.

Size of TBS: length of the TBS.

Time interval: days before and after removal of TBS fixator.

Retraction distance and nine risk factors are shown in table 1.

Table 1 Descriptive statistics of variables

Retraction distance(mm)	8.08±6.39
Age(yrs)	39.95±14.83
Gender(m/f)	22/15
Disease course(day)	40.54±25.65
Size of TBS(mm)	91.03±15.18
Length of defect(mm)	64.10±11.55
Time interval(day)	9.22±3.95
Timing of removal(day)	7.47±1.94
Times of operation(Num)	1.65±0.82
Transport distance(mm)	68.40±13.41

2.4 Statistical analysis

Data analysis was performed using SPSS 20.0 statistical software (IBM, New York, USA). Firstly, scatter diagram and bivariate correlation were used to analyze relationships between retraction distance and nine factors including age, gender, disease course, length of bone defect, times of operation, size of TBS, transport distance, timing and time interval of removal of TBS fixator. Risk factors with significant level were further identified using multivariate linear regression. $P<0.05$ was considered significant.

3. Results

Correlation between the retraction distance and nine variables using scatter diagram showing variables for access analysis were timing of removal, time interval, and transport distance, Fig.1. Bivariate correlation analysis showed that the timing of removal was negatively correlated with the retraction distance ($r=-0.832$, $P=0.000$), while the time interval and transport distance were positively correlated with the transport distance（$r=0.368$, $P=0.025$, $r=0.337$, $P=0.041$ respectively); However the age, gender, disease course, size of TBS, bone defect length and times of operation were not correlated with the transport distance（$r=-0.121$, $P=0.475$，$r=0.020$, $P=0.907$, $r=-0.247$, $P=0.140$, and $r=0.150$, $P=0.377$, $r=0.006$, $p=0.974$, $r=0.312$, $p=0.060$, respectively). Multivariate linear regression analysis of the 3 risk factors showed that the timing of removal and time interval were main risk factors for the retraction distance of TBS (table 2), of which, the timing of removal had the greatest impact ($t=-10.171$, $p=0.000$), followed by the time interval ($t=3.193$，$p=0.003$), but the transport distance was not a main risk factor for the retraction distance ($t=-0.717$，$p=0.479$). Regression equation: $Y=27.070-2.808X1+0.449X2$. Scatter diagram of regression model of standardized predicted value of retraction distance seen Fig. 2. Typical cases are shown in Fig. 3-4.

Table 2. Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	27.070	3.960		6.836	.000
Timing of removal	-2.808	.276	-.851	-10.170	.000
Time interval	0.449	.140	.277	3.193	.003
Distraction distance	-0.031	.044	-.066	-.717	.479

a. Dependent Variable: retraction distance

4. Discussion

Distraction osteogenesis is to perform slow bone transport or lengthening using external distraction system or intramedullary distraction system after osteotomy. The resistance force of the TBS suffered comes from two aspects during bone transport: one is generated from the distraction of the soft tissues of TBS, and the other is generated from callus distraction at the lengthening site. They come from different sites or directions, and have different properties.

The whole distraction osteogenesis process is divided into three phases: 1-2 weeks of latency period, then about 3-4 months of distraction period, and at last another 3-4 months of consolidation period [12,15]. The callus distraction gradually appears at distraction period, then gradually becomes dense, and finally it matures at consolidation period. Complete mineralization of the callus distraction (complete consolidation) can prevent the retraction of TBS.

Although the periosteal connection was cut off after osteotomy, there were still adherent structure of the TBS such as fascia, tendon or muscle, nerve, vessels, skin, tendons, ligaments and the connections among them. The magnitude of the traction force from soft tissues reported differs by different authors [10-13], which is mainly related to the transport distance, site and size of TBS. The thicker the skeleton, or the longer the TBS and transport distance, the greater the force[10-13]. Horas et al. [11] used eight cadaveric thigh specimens to make a 60 mm bone defect at the middle femur, and then assessed the traction force required for 40-mm and 60-mm long of TBS using a novel type of intramedullary distraction system. The results showed that the traction force generated by soft tissue was linearly correlated with the transport distance; after a period of sharply increase in force at 0-10 mm transport distance, a relatively slow increase in force at 10-50 mm distance, whereas it again increased rapidly up to a maximum of 444.5 N at 50-60 mm transport distance; the traction force required for 60-mm long of TBS was higher than that for 40-mm long of TBS. The study indicated that transport distance and the size of TBS were closely related to the magnitude of traction force generated by its adjacent soft tissues. However, the timing of removal was not considered in this study.

There were still different opinions on the main traction force of the TBS endured during bone transport [10-12]. Aronson et al. [11] concluded that with the increase of transport length, the traction force generated by callus distraction gradually increases, which is greater than the traction force generated by soft tissues. However, Wolfson et al. [12] considered that the soft tissues play a decisive role in traction force generation. We believe that two kinds of traction forces of the TBS change dynamically during bone transport. In the early stage (within 3 months after bone transport), the traction force from the soft tissues is great than that from the callus distraction and becomes an important role; in the middle stage (3-6 months after bone transport), the former reaches its peak and the latter gradually increases; in the late stage (>6 months after bone transport), the former becomes small, the latter gradually increases and becomes an important role. The former has elastic properties, whereas the latter does not have elastic properties and has anti-retraction properties, which can prevent the retraction of TBS [10-14]. Therefore, the retraction of TBS is induced by soft tissue, rather than callus distraction. Juzheng H et al [7] reported on patients with large tibia bone defect treated by bone transport using external distraction system and relay plate internal fixation, certain degree of retraction often observed in their study. In this study, most patients with retraction of TBS were within 8 months postoperatively, 3 patients were in more than 10 months postoperatively due to delayed mineralization; the callus distraction in all patients with retraction of TBS was incompletely mineralized, i.e. the timing of removal is closely related to the magnitude of traction force.

Beside distraction force, time interval is another important factor influencing retraction distance of TBS. The longer the time interval, the more the retraction. In the typical case 1 of this study, the timing of TBS removal was earlier (3.5 months), the time interval was longer (25 days) , which resulted in great retraction (30 mm). Our study showed that the timing of removal and time interval are the key factors influencing the retraction of TBS, especially the timing had the greatest impact, followed by the time interval, but the transport distance and size of TBS are not key factors influencing the retraction of TBS.

Understanding the force and retraction phenomenon of TBS during bone transport is helpful to take corresponding measures to avoid adverse effect or complications. For example, the ends should be pressurized for 2 ~ 3 weeks when the docking site is closed in traditional bone transport; the earlier the time of removal of fixator, the longer the time interval, the larger the retraction distance. In this situation, another external fixation method should be used to avoid the adverse effect of more retraction of TBS on the healing of the the docking site. Otherwise more bone graft is needed because it is difficult to complete the reduction and closure.

This study explored the causes and relevant factors of the retraction of TBS during Ilizarov bone transport. The findings of this study are useful for understand of the retraction of TBS, improving prognosis and reducing complications of bone transport in the treatment of bone defect.

Conclusions

The TBS is always endured two aspects of distraction forces- generated by the distraction of the soft tissues of TBS and callus distraction at the lengthening site. The force generated by soft tissues has elastic properties and can induce a retraction of TBS when the TBS fixator or total external fixator is removed before complete mineralization of the callus distraction and union of the docking site. The retraction distance is influenced by the timing of removal, the time interval, transport distance and size of the TBS. However, the timing of removal and the time interval are the key factors influencing the retraction of TBS. In order to reduce the gap caused by retraction of TBS especially when the fixator was removed in early stage of bone transport, the time interval should not be long or use another external fixation to avoid the adverse effect of retraction of the TBS on the healing of the docking site.

Abbreviations

TBS:transporting bone segment

Declaration

- **Ethics approval and consent to participate**

All procedures performed in studies involving human participants were in

accordance with the ethical standards of the institutional standards. Informed consent was obtained from all individual participants included in the study.

- **Conflict of interest**

The authors declare that they have no conflict of interest.

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- **Authors' contributions**

YH M and XF H put forward the concept of this study and designed this experiment, YW W and SJ G revised this manuscript. QD Y, ZN W, YJ R and ZZ S collected data and performed the statistical analysis. All authors read and approved the final manuscript.

- **Consent for publication**

Informed consent was obtained from all individual participants included in the study.

- **Availability of data and material**

Not applicable.

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Figures

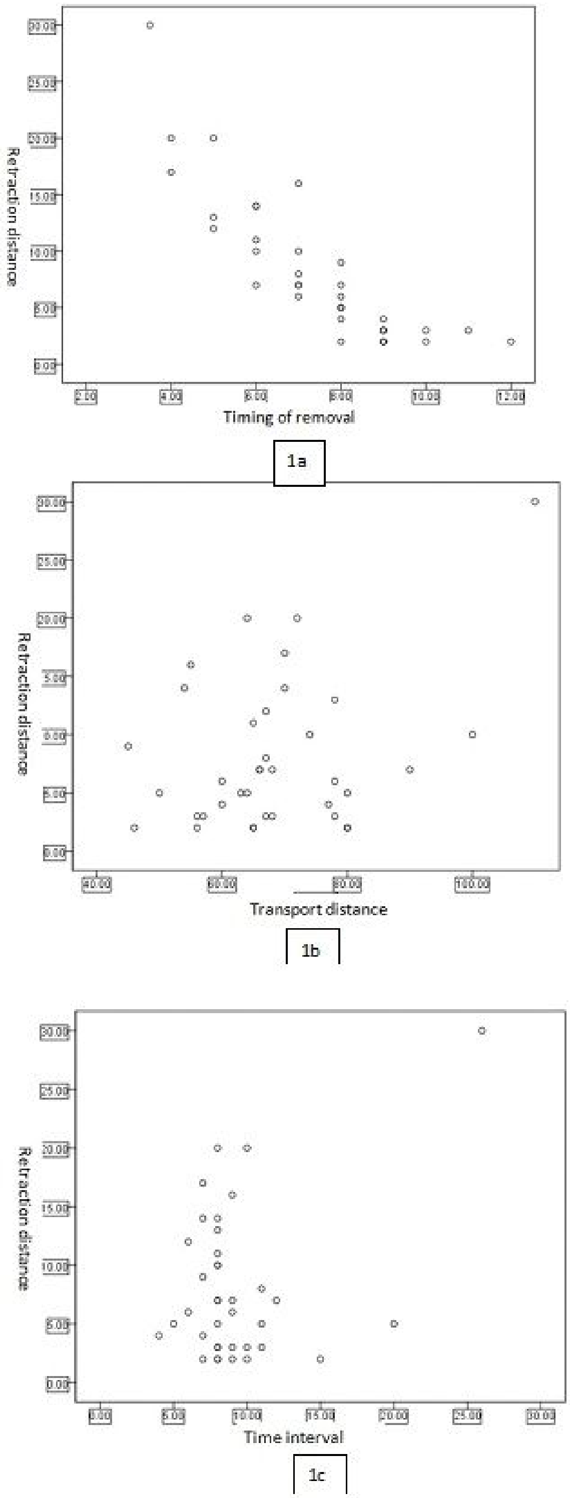

Figure 1

Scatter diagrams of the timing of removal(a), transport distance(b) and time interval of removal(c)

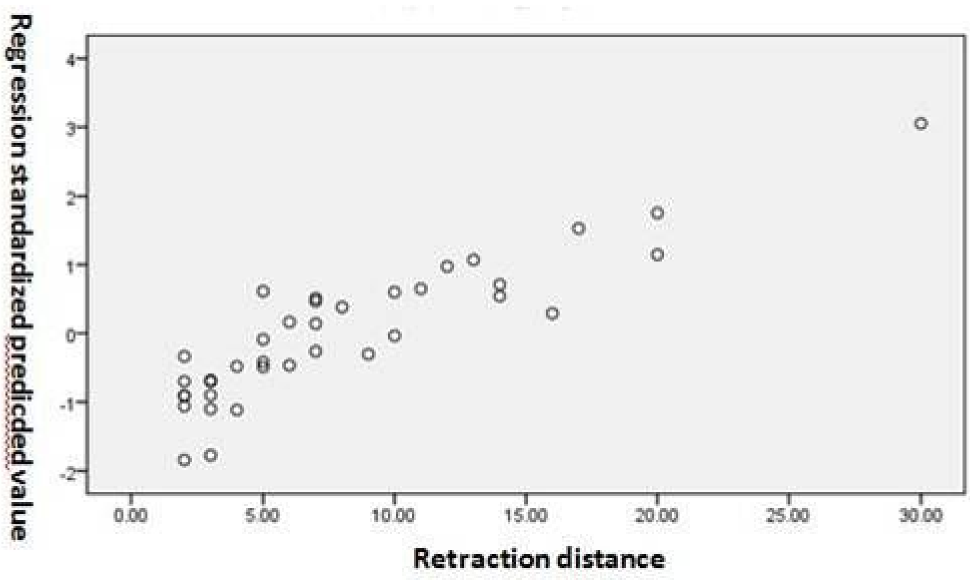

Figure 2

Scatter diagram of the regression model

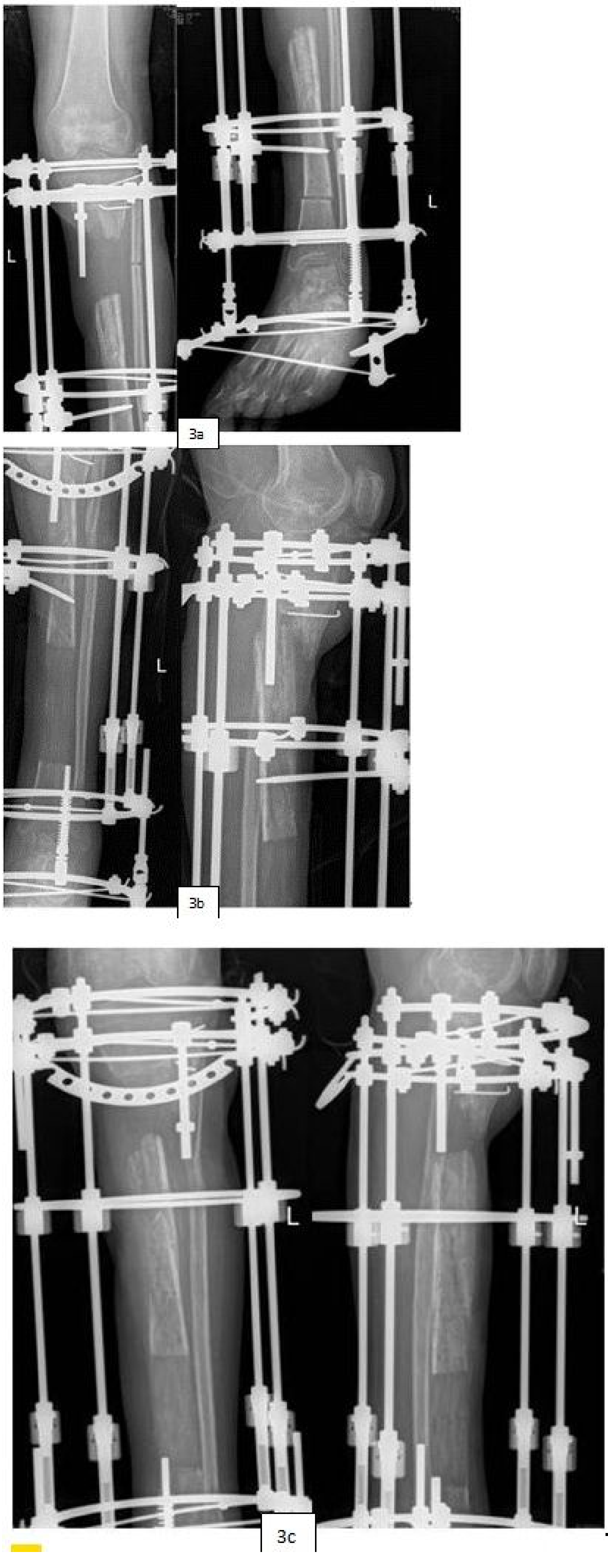

Figure 3

Fracture and defect of tibia and fibula treated by bone transport (a,b), the TBS retracted 3.0 cm after removal of TBS fixator in 3.5 months postoperatively in a time interval of 25 days(c).

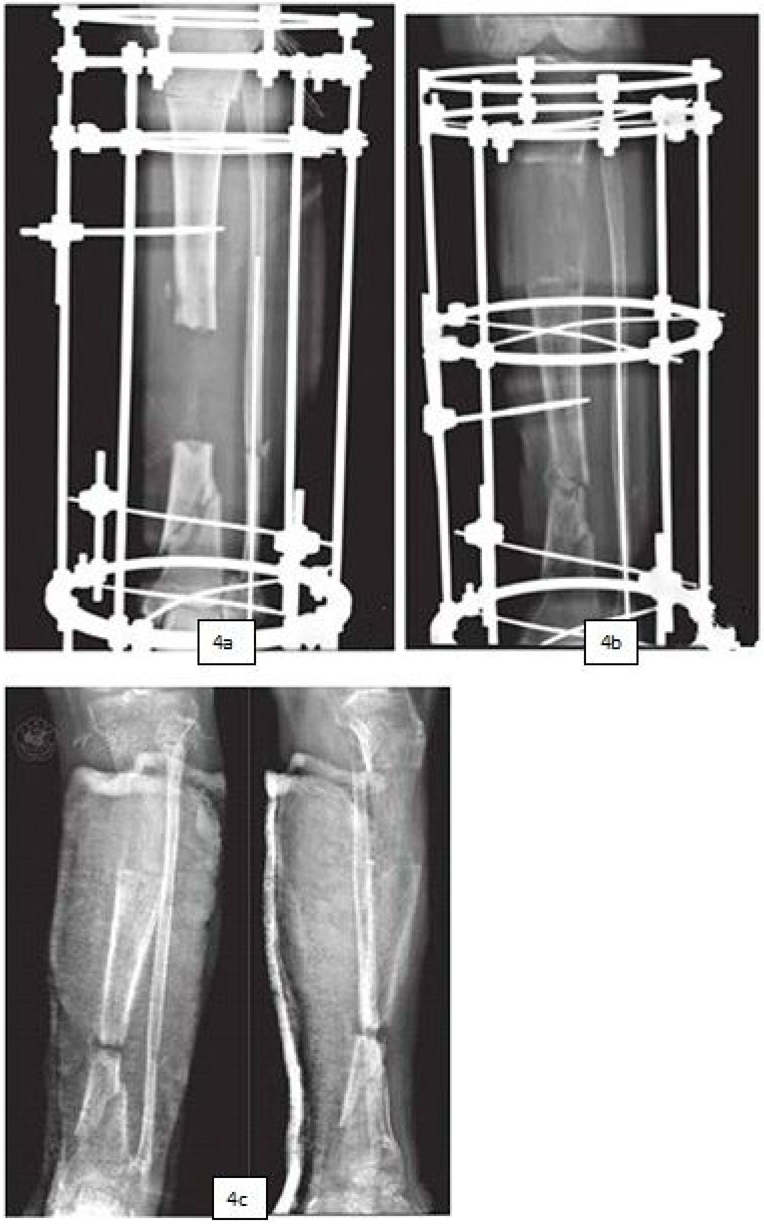

Figure 4

Fracture and defect of tibia and fibula treated with bone transport (a,b), the TBS retracted 4.0 mm after removal of total external fixator in 7 months postoperatively in a time interval of 10 days(c).