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Application research of two types of self-made tibial fracture traction and reduction devices in intramedullary nail fixation for tibial fractures

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Abstract: *To explore the clinical application effects of two self-made tibial fracture traction and reduction devices in intramedullary nailing for tibial shaft fractures. A total of 63 cases treated with intramedullary nailing for tibial shaft fractures from January 2019 to October 2025 were analyzed and divided into three groups: A,B and C. Group A underwent surgery with an assistive traction and temporary fixation using a self-made ring-type axial traction multi-plane adjustment reduction device. Group B utilized a self-made small tibial fracture traction and reduction device for assistive traction and temporary fixation. Group C received traditional two-assistant traction and fixation plus intramedullary nailing. The surgical duration, intraoperative fracture reduction time, fluoroscopy frequency, intraoperative blood loss, postoperative fracture healing time, complications and Johner-Wruhs functional scores were compared among the three groups. All 63 patients successfully completed the surgery and were followed up for 3-26 months. Group A and Group B showed significantly shorter surgical duration, intraoperative fracture reduction time, fluoroscopy frequency and intraoperative blood loss compared to Group C with statistically significant differences ($P<0.05$). No statistically significant difference was observed between Group A and Group B ($P>0.05$). No significant differences were found among the three groups in postoperative fracture healing time, complications and Johner-Wruhs functional scores ($P>0.05$). The two self-made tibial fracture traction and reduction devices can assist in traction and temporary fixation during intramedullary nailing for tibial fractures, reducing assistant workload, shortening intraoperative fracture reduction time and surgical duration, decreasing fluoroscopy time, and minimizing intraoperative blood loss. They demonstrate favorable clinical outcomes and are worthy of clinical promotion.*

Keywords: *Tibial fracture, Intramedullary nail fixation, Tibial fracture traction reducer*

1. Introduction

Tibial shaft fractures are one of the most common types of long tubular bone fractures, accounting for approximately 6.8% of all fractures in the body[1]. There are various clinical treatment methods for tibial shaft fractures, among which interlocking intramedullary nails are used for axial fixation, featuring Balanced force distribution, anti-rotation, anti-shortening, and stable fracture fixation[2-3]. Moreover, intramedullary nail fixation can maximize the preservation of the periosteum at the fracture site while minimizing the dissection of soft tissues, providing the possibility for early weight-bearing[4-6]. Therefore, it is the gold standard for treating displaced tibial shaft fractures in adults[7-8], and is widely used in the treatment of tibial shaft fractures. In the traditional intramedullary nail internal fixation surgery through the patellar groove approach, a dedicated assistant is required to flex the knee and hold the distal end of the thigh to resist traction and fix the affected limb, and another assistant is needed to pull and reset the distal part of the fracture to facilitate the gradual expansion of the canal by the surgeon for fixation. The two assistants are quite hardworking. To alleviate the burden on the assistants, our hospital has independently developed two tibial fracture traction and reset devices, and both have obtained national utility model patents and been authorized. Our orthopedic department has applied the two independently developed tibial fracture traction and reset devices in the intramedullary nail internal fixation surgery for tibial shaft fractures, providing auxiliary traction and reset and temporary fixation for tibial fractures, achieving good results. The results are reported as follows.

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2. Materials and Methods:

2.1 General information

A total of 63 patients with tibial shaft fractures who were admitted to our hospital from January 2019 to October 2025 were selected; they were divided into three groups: A, B and C with 21 cases in each group. Inclusion criteria: age 18-68 years; closed tibial shaft fractures. Exclusion criteria: pathological fractures; non-healing after fracture surgery. Comparisons of gender, age, time from injury to surgery, and fracture classification among the three groups showed no statistically significant differences ($P > 0.05$), and they were comparable. See Table 1. Group A: Tibial shaft fractures were treated with intramedullary nail internal fixation surgery, and during the operation, a self-made ring-shaped axial traction multi-plane adjustment reduction device was used for auxiliary traction reduction and temporary fixation treatment. Group B: Tibial shaft fractures were treated with intramedullary nail internal fixation surgery, and during the operation, a self-made small tibial fracture traction reduction device was used for auxiliary traction reduction and temporary fixation treatment. Group C: Traditional tibial shaft fracture intramedullary nail internal fixation surgery was performed. One assistant held the distal end of the thigh in a flexed position to counteract traction and fix the affected limb, and another assistant performed traction reduction and fixation of the fracture distal part, while the surgeon performed the reaming and insertion of the tibial intramedullary nail surgery.

Table 1: Comparison of general data of the three groups of patients.

group	n	gender		age(y)	time from injury to surgery (d)	AO classification of fractures		
		Man	woman			A	B	C
A	21	18	3	35.8±1.2	6.4±1.3	10	7	4
B	21	16	5	35.9±1.1	6.2±1.2	9	8	4
C	21	17	4	36.1±1.2	6.5±1.1	11	7	3
$t(X^2)^{[A,B]}$		0.155		0.748	0.662	0.791		
$t(X^2)^{[A,C]}$		0.157		0.751	0.665	0.792		
$t(X^2)^{[B,C]}$		0.159		0.756	0.667	0.793		
$P^{[A,B]}$		0.785		0.492	0.589	0.689		
$P^{[A,C]}$		0.782		0.489	0.587	0.687		
$P^{[B,C]}$		0.779		0.483	0.585	0.686		

2.2 Surgical procedure

2.2.1 Group A

The anesthesia is continuous epidural anesthesia. The patient lies in a supine position. An air pressure tourniquet is placed proximal to the affected limb thigh, with a pressure of 75 kPa. The skin is routinely disinfected and draped, and the tourniquet is tightened. A suitable thick Kirschner wire is inserted through the appropriate hole on the ring-shaped surface of the self-made ring-shaped axial traction multi-planar adjustment retractor at the appropriate position on the ring, passing through the appropriate positions of the distal and proximal ends of the tibia, and then pulling the traction ring-shaped retractor to perform traction and reduction of the fracture ends (Figure 1).The C-arm X-ray machine is used for fluoroscopic verification of the reduction, and then the screw on the traction retractor is fixed with a nut. Thus, the tibial shaft fracture can be temporarily reduced and fixed. After stable fixation, the knee joint can be flexed to 120 degrees (Figure 2).The surgeon makes a longitudinal incision about 4 cm long on the lower pole of the patella of the affected limb, slightly to the inner side of the tibial tubercle in the direction of the patellar ligament medial edge, along the medial edge of the patellar ligament, to expose the sliding slope above the tibial tubercle, determine the entry point, insert the sharp cone, insert the intramedullary nail guide and gold finger. At this time, no assistant is needed to specifically pull and fix the reduction (Figure 3). Posteroanterior and lateral fluoroscopy determine the fracture position and the position of the guide pin (Figure 4). After expanding the marrow cavity, an appropriate type of intramedullary nail is inserted (Figure 5). Two distal locking screws were locked first. After applying counter-pressure to the fracture site with a targeting device, two proximal locking screws and the tail cap of the intramedullary

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nail were locked. Finally, fluoroscopy shows that the alignment and line of the tibial fracture are good, and the position of the intramedullary nail is appropriate (Figure 6). The incision was sutured layer by layer, the tourniquet was released, and the wound was dressed with sterile dressing.

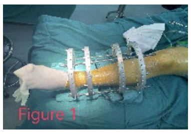

Figure 1: Intraoperative assistance for traction and reduction using the ring-shaped axial traction device

Figure 2: The knee joint can be flexed to 120 degrees

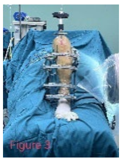

Figure 3: Through the patellar lower approach, the intramedullary nail guide and the gold finger were inserted

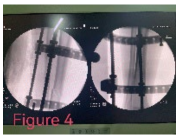

Figure 4: During the operation, frontal and lateral X-rays were taken.

Figure 5: An appropriate type of intramedullary nail is inserted

Figure 6: Fluoroscopy shows that the alignment and line of the tibial fracture are good, and the position of the intramedullary nail is appropriate

2.2.2 Group B

The anesthesia was continuous epidural anesthesia. The patient was placed in a supine position, and a pneumatic tourniquet was applied to the proximal end of the affected thigh with a pressure of 75 kPa. After routine disinfection and draping, the tourniquet was tightened. The affected limb was placed on a small tibial fracture reduction and traction device developed by our hospital for traction and reduction (Figure 7). The affected limb was fixed with the knee flexed at 120 degrees (Figure 8). A longitudinal incision of about 4 cm was made about 1.5 cm above the tibial tubercle, slightly medial. The fascia was incised longitudinally, and the area above the tibial tubercle was exposed through the medial side of the patellar ligament. The entry point was determined, and a sharp cone was used to make an incision. Then, the medullary cavity was gradually expanded with small-sized reamers. A suitable intramedullary nail was selected and inserted in an antegrade direction (Figure 9). The position of the fracture and the intramedullary nail was observed under C-arm X-ray (Figure 10). Two distal locking screws were locked first. After applying counter-pressure to the fracture site with a targeting device, two proximal locking screws and the tail cap of the intramedullary nail were locked. The external fixation device was removed, and the position of the fracture and the intramedullary nail was observed under C-arm X-ray (Figure 11). The incision was sutured layer by layer, the tourniquet was released, and the wound was dressed with sterile dressing (Figure 12).

Figure 7: The affected limb was placed on a small tibial fracture reduction and traction device developed by our hospital for traction and reduction

Figure 8: The affected limb was fixed with the knee flexed at 120 degrees

Figure 9: A suitable intramedullary nail was selected and inserted in an antegrade direction

Figure 10: The position of the fracture and the intramedullary nail was observed under C-arm X-ray

Figure 11: The external fixation device was removed, and the position of the fracture and the intramedullary nail was observed under C-arm X-ray

Figure 12: The wound was dressed with sterile dressing

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2.2.3 Group C

The patient lies in a supine position, and a pneumatic tourniquet is placed on the proximal end of the affected thigh. After routine disinfection and draping, the tourniquet is tightened. One assistant holds the distal end of the affected thigh and flexes the knee at 120 degrees to fix and counter-traction the limb. Another assistant needs to traction the distal end of the tibia fracture and hold the fracture site. The surgeon makes a longitudinal incision of about 4 cm along the medial edge of the patellar ligament from the lower pole of the patella towards the tibial tubercle. The fascia is cut longitudinally, and the incision is made from the medial side of the patellar ligament to fully expose the slip-off position above the tibial tubercle and determine the entry point. A sharp cone is used to make an entry. The assistant holding the distal end of the affected thigh needs to apply force for counter-traction. The assistant holding the distal end of the tibia needs to apply force to traction and reset the fracture and hold the fracture site, maintaining the good reduction of the tibial fracture site. The surgeon accurately places the "golden finger" and guide pin. The C-arm X-ray machine is used to observe the position of the fracture and the tail of the guide pin. If the position of the fracture and the tail of the guide pin is appropriate, the reaming can be gradually performed. If the position of the fracture and the tail of the guide pin is inappropriate, the reduction and fixation need to be redone and the guide pin reinserted until the position of the fracture and the guide pin is appropriate. Otherwise, it is difficult to avoid the deviation of the tibial force line after the intramedullary nail is inserted. Ensure that the tibial fracture is well reduced and aligned. After the position of the guide pin is appropriate, reaming is performed successively with small-sized reamers. During this stage, the assistant holding the distal end of the tibia needs to apply force to hold and fix the fracture site to maintain the good reduction of the tibial fracture site. After reaming, the appropriate-sized intramedullary nail is inserted in an antegrade manner. The C-arm X-ray machine is used to observe the position of the fracture and the intramedullary nail. If the fracture is well reduced and aligned and the position of the intramedullary nail is appropriate, the distal locking is locked first. After the fracture site is counter-pressed with a targeting device, the proximal locking and the tail cap of the intramedullary nail are locked. The C-arm X-ray machine is used to observe the position of the fracture and the intramedullary nail. The wound is sutured layer by layer, and the wound is dressed with sterile dressings. The tourniquet is released.

2.3 Postoperative management

Within 24 hours after the operation, first-generation cephalosporin antibiotics are routinely used to prevent wound infection. All patients are followed up. X-ray films are re-examined at 1 week, 1 month, 2 months, and 3 months after the operation, and then every 3 to 6 months. On the first day after the operation, isometric contraction exercises of the muscles of the affected limb are started. On the second day after the operation, sitting up and passive and active functional exercises of the lower limb joints are initiated. On the fifth day after the operation, patients practice standing with the affected limb not bearing weight with the aid of a walker. One week after the operation, patients can move around with the affected limb not bearing weight and with the aid of a walker. Two weeks after the operation, patients can stand with a small amount of weight on the affected limb with the aid of a walker. One month after the operation, the degree of weight-bearing on the affected limb is gradually increased based on the fracture healing condition shown on X-ray films. For patients with slow fracture healing or osteoporosis, the time for weight-bearing is appropriately postponed.

2.4 Efficacy evaluation

The surgical time, fracture reduction time during the operation, the number of X-ray examinations during the operation, intraoperative blood loss, postoperative fracture healing time, postoperative complications, and postoperative Johner-Wruhs functional score of the three groups were compared. The Johner-Wruhs score[9] includes: whether there are nerve and vascular disorders and limb deformities, the range of joint movement of the affected limb, pain, gait, etc., which is classified as excellent, good, fair, or poor.

2.5 Statistical methods

The SPSS 23.0 software was used to conduct statistical analysis and comparison between each pair of the three groups of collected data. The t-test was used for the comparison of two sample means for the measurement data, and the x^2 test was used for the count data. P value less than 0.05 indicated a statistically significant difference in comparison.

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3. Results

Clinical efficacy comparison: All patients were followed up after surgery, with follow-up periods ranging from 3 to 26 months, averaging 15 months. There were no cases of fixed failure in any of the three groups. One case of delayed healing of the lower patellar wound occurred in each of the three groups, and the wounds healed after dressing changes. The operation time, fracture reduction time during the operation, the number of X-ray examinations during the operation, and the intraoperative blood loss in group A were significantly less than those in group C. Comparisons between the two groups showed statistically significant differences ($P < 0.05$, Table 2). The operation time, fracture reduction time during the operation, the number of X-ray examinations during the operation, and the intraoperative blood loss in group B were also significantly less than those in group C, and the differences between the two groups were statistically significant ($P < 0.05$, Table 2). There were no statistically significant differences in the operation time, fracture reduction time during the operation, the number of X-ray examinations during the operation, and the intraoperative blood loss between group A and group B ($P > 0.05$, Table 2). There were no statistically significant differences in the postoperative fracture healing time, postoperative complications, and postoperative Johner-Wruhs functional score among the three groups ($P > 0.05$, Table 3).

Table 2: Comparison of Intraoperative Data among the Three Groups.

group	n	the surgical time (min)	the fracture reduction time during the operation (min)	the number of X-ray examinations during the operation	intraoperative blood loss (ml)
A	21	45.3±11.0	10.1±1.8	6±1.0	30.0±2.0
B	21	46.4±12.1	10.5±2.0	6±1.2	31.0±4.0
C	21	67.4±13.6	18.0±2.2	9±1.0	48.0±5.0
$t(X^2)^{[A,B]}$		0.675	0.563	0.632	0.673
$t(X^2)^{[A,C]}$		5.650	8.32	6.47	7.23
$t(X^2)^{[B,C]}$		5.648	8.26	6.68	7.57
$P^{[A,B]}$		0.535	0.532	0.545	0.612
$P^{[A,C]}$		<0. 001	<0. 001	<0. 001	<0. 001
$P^{[B,C]}$		<0. 001	<0. 001	<0. 001	<0. 001

Table 3: Comparison of postoperative efficacy follow-up among three groups

group	n	Postoperative fracture healing time (d)	Postoperative complications/case	Postoperative Johner-Wruhs score excellent rate per case (%)
A	21	120.0±6.0	1	90.5
B	21	121.0±4.0	1	87.7
C	21	122.0±5.0	1	85.7
$t(X^2)^{[A,B]}$		1.678	—	—
$t(X^2)^{[A,C]}$		1.650	—	—
$t(X^2)^{[A,C]}$		1.649	—	—
$P^{[A,B]}$		0.397	0	0.67
$P^{[A,C]}$		0.365	0	0.56
$P^{[B,C]}$		0.389	0	0.69

4. Discussion

Regarding the treatment of tibial shaft fractures, the advantage of intramedullary nails over plates is that they cause less trauma and involve less soft tissue dissection. Closed reduction of tibial fractures can maximize the preservation of blood supply at the fracture ends, maintain the nutritional supply for fracture healing, and the self-grafting effect produced by expanding the marrow cavity is beneficial for fracture healing[10]. The patellar lower approach and patellar upper approach for treating tibial shaft fractures can both achieve satisfactory internal fixation results[11] . The traditional knee flexion position

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patellar lower approach with intramedullary nail internal fixation for tibial fractures has been recognized by most clinicians as an effective treatment method, but it also has some limitations: 1) In the knee flexion position, the anterior patellar ligament incision requires extreme knee flexion to ensure the accuracy of the opening position of the intramedullary nail on the tibial tuberosity. In this state, it is difficult to achieve good reduction and maintain the reduction, often resulting in the loss of the fracture end reduction [12]; 2) Under the knee flexion condition, the operation under C-arm X-ray machine fluoroscopy is difficult and cannot accurately obtain standard imaging data, thereby affecting the assessment of fracture reduction and the position of the intramedullary nail [13]. To avoid the above possible problems during the operation, in the specific operation of expanding the marrow cavity and inserting the intramedullary nail in the traditional tibial fracture intramedullary nail internal fixation, one assistant is required to specifically hold the distal end of the affected limb thigh in a 120° knee flexion position for traction and counter-fixation, and another assistant is required to reduce and fix the fracture ends of the tibial fracture. The assistant is very hardworking, and the surgeon often causes the fracture ends to repeatedly move during the gradual expansion of the marrow cavity, causing secondary damage to the surrounding soft tissues and blood supply, and when the knee is at 120°, due to the tibial shaft fracture, the lower leg cannot be effectively fixed without external force assistance, and cannot perform accurate tibial anteroposterior C-arm X-ray machine fluoroscopy. To solve these problems, Dr. Wei Songying reported that the reverse support adjustable support device was used to assist intramedullary nail treatment of tibial fractures [14] . Our department's orthopedics department, based on the long-term experience and understanding of closed reduction intramedullary nail internal fixation for tibial fractures, has designed the ring-shaped axial traction multi-plane adjustment reducer and the small tibial fracture traction reducer. Using these two reducers for reduction and temporary fixation of the tibial fracture ends facilitates the surgeon's expansion of the marrow cavity and insertion of the intramedullary nail, solving the problem of fracture end reduction loss during expansion and insertion, and facilitating intraoperative fluoroscopy.

Our orthopedic department has applied the self-developed ring-shaped axial traction multi-plane adjustment retractor and the small-sized tibial fracture traction retractor in the intramedullary nail surgery for tibial shaft fractures, and conducted a comparative study with traditional treatment methods. Through the comparative analysis of the surgical time, the time for fracture reduction during the operation, the number of fluoroscopic examinations during the operation, the intraoperative blood loss, the postoperative fracture healing time, postoperative complications, and the postoperative Johner-Wruhs functional score of the patients, we summarized the following functions of the ring-shaped axial traction multi-plane adjustment retractor and the small-sized tibial fracture traction retractor in the intramedullary nail internal fixation surgery for tibial fractures: 1.Supporting and fixing the fractured lower leg, reducing the re-injury of the surrounding soft tissues by the fracture fragments during the operation; 2.Traction and distraction to shorten the shortened tibial fracture fragments and provide fixation, shortening the repositioning time of the tibial fracture fragments during the operation, shortening the operation time, and reducing the number of fluoroscopic examinations; 3.Reducing the obstruction of the assistant and opening the surgeon's field of vision; 4.Avoiding excessive movement of the affected limb and reducing the probability of contamination; 5.The ring-shaped axial traction multi-plane adjustment retractor does not affect the insertion of the intramedullary nail or the fluoroscopic examination during the operation. The ring-shaped axial traction multi-plane adjustment retractor and the small-sized tibial fracture traction retractor have the characteristics of simple operation, rapid repositioning, reliable and long-lasting fixation, and are conducive to the operation. They have a good auxiliary effect on the operation of tibial fracture interlocking intramedullary nail surgery.

The ring-shaped axial traction multi-plane adjustment retractor and the small-sized tibial fracture traction retractor developed by our hospital have applied for national patents and have been authorized. Moreover, the ring-shaped axial traction multi-plane adjustment retractor and the small-sized tibial fracture traction retractor developed independently by our hospital are made of stainless steel, can be disinfected at high temperatures, can be reused, and are simple to operate. They are worthy of clinical promotion and application. This study also has limitations, such as being a single-center retrospective study, with a small sample size, and a low clinical evidence level. More multi-center large-sample clinical research evidence is still needed. This is also the technical promotion we need to carry out in the future.

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