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Application of distal femoral 90° locking plate in children with supracondylar femoral fractures

Y.-J. ZHANG[1], Y.-J. WANG[2], S.-H. WANG[3], X.-L. SONG[3], N. ZHAO[3]

[1]Pediatric Orthopedics Department of Bone Oncology, Cangzhou Hebei Integrated Traditional Chinese and Western Medicine Hospital, Cangzhou, China
[2]Outpatient Dressing Room, Cangzhou Central Hospital, Cangzhou, China
[3]Department of Orthopedics, Cangzhou Hebei Integrated Traditional Chinese and Western Medicine Hospital, Cangzhou, China

Abstract. – OBJECTIVE: This study aimed to assess the application value of distal femur 90° locking plate fixation for supracondylar femoral fractures (SFF) in children.

PATIENTS AND METHODS: A total of 100 SFF children with or without diabetes who were enrolled in our hospital from January 2018 to January 2020 were randomized into a control group and a study group by the random number table method. The study group received distal femur locking plate fixation, and the control group adopted Kirschner wire (K wire) internal fixation. The primary outcomes of the two groups of children and the secondary outcomes of the diabetic patients were compared.

RESULTS: The fracture union rate of the study group was significantly higher than that of the control group at 12 weeks, 16 weeks, 20 weeks and 24 weeks after the operation (*p*<0.05), while the rate showed no significant difference between the two groups at 28 weeks after the operation (*p*>0.05). The two groups showed similar operation time, intraoperative blood loss, intraoperative fluoroscopy time, and hospital stay (*p*>0.05). The study group yielded a more favorable outcome with regard to the Harris-Hip-Score (HHS) scores, HHS excellent-and-good rate, and Flynn scores satisfaction rate than the control group (*p*<0.001 or 0.05). The intracavitary pressure of the knee joint of the two groups presented a gradual decline with time, with remarkably lower results in the study group compared with the control group at 8 weeks and 16 weeks after the surgery (*p*<0.05), and differences at 24 weeks after the surgery did not come up to the statistical standard (*p*>0.05). Patients experienced fewer postoperative complications after locking plate fixation, as compared to those who received K wire treatment (*p*<0.05). Compared with the control group, the fracture union rate of diabetic children in the study group was significantly higher at 12 weeks, 16 weeks, and 20 weeks after surgery, respectively (*p*<0.05), while there was no significant difference between the two groups at 24 weeks and 28 weeks (*p*>0.05).

CONCLUSIONS: The distal femur 90° locking plate fixation for diabetic children with SFF obviates the need for plate shaping and ensures firm fixation, with biomechanical design, promising efficacy, and few complications. The distal femur 90° locking plate fixation has better efficacy for children with diabetes. It shows great potential as the treatment of choice for diabetic children with SFF.

Key Words:
Supracondylar femoral fractures, Locking plate, Kirschner wire, Diabetes, Knee joint function, Intracavitary pressure of the knee joint.

Introduction

Supracondylar femoral fractures (SFF) refer to fractures that occur within 7 cm of the articular surface of the femoral condyle. It accounts for 7.5% to 12% of femoral fractures in children, mostly caused by falling from a height[1]. In SFF, the fracture line is between the femoral condyle and the metaphysis, close to the articular surface, which may compromise joint movement. Corresponding treatment is to achieve anatomical reduction, restore the normal length of the lower limbs, correct rotation and axis, and ensure sufficient stability to facilitate the patient's early functional exercise and rehabilitation[2,3]. Given the incomplete fusion between the epiphysis and the metaphysis of children, epiphyseal damage should be avoided during treatment to prevent abnormal skeletal growth or developmental disorders. Previous treatment methods mostly include conservative plaster treatment, traditional traction treatment, and percutaneous Kirschner wire (K wire). Nevertheless, these treatment methods are associated with a high risk of fracture re-displacement and malunion. Moreover, the use of plates

Corresponding Author: Y.-J. Zhang, MD; e-mail: yuao032@126.com

for other body parts is laborious in shaping, prolongs the operation time, and increases the pain of children, while external fixation is associated with insecure fracture fixation, inconvenience for nursing, nail tract infection, and late joint stiffness[4,5].

Some studies[6,7] have reported that a long-term lack of proper exercise after fractures results in stiffness and decreased joint mobility. Affected by postoperative immobilization and immobilization of injured limbs, patients are prone to complications such as joint stiffness and muscle atrophy. An effective treatment plan to relieve postoperative knee stiffness and promote the recovery of knee joint function is the key topic of current clinical research. Traditional Chinese medicine believes that trauma can easily damage the collaterals, thus forming a syndrome of qi stagnation and blood stasis, disturbing normal activities. Diabetes is a common chronic non-communicable disease, and children with type 1 diabetes may have a worse bone microstructure and increased fracture risk[8]. However, the difference between the distal femur 90° locking plate fixation and the Kirschner wire internal fixation for diabetic children with SFF remains unclear. In view of this, the present study adopted the distal femur 90° locking plate fixation for SFF children with or without diabetes and achieved excellent results. The results are now reported as follows.

Patients and Methods

General Information

A total of 100 children with SFF who were enrolled in our hospital from January 2018 to January 2020 were randomized into a control group and a study group by the random method.

The randomization was carried out using an online web-based randomization tool (freely available at http://www.randomizer.org/). For concealment of allocation, the randomization procedure and assignment were managed by an independent research assistant who was not involved in the screening or evaluation of the participants.

The study was conducted according to Good Clinical Practice guidelines developed by the International Council for Harmonisation and in compliance with the study protocol. The protocol was approved by the Institutional Review Boards of Cangzhou Hebei Integrated Traditional Chinese and Western Medicine Hospital (LOPO202180202). All patients provided written informed consent per the Declaration of Helsinki principles. An independent data monitoring Committee monitored the safety and efficacy of data.

Inclusion criteria: (1) 6-14 years old; (2) follow-up time>1 year; (3) diagnosed with SFF by imaging[9]; (4) closed fractures; (5) the guardians of the children signed the informed consent form after being fully informed of the study.

Exclusion criteria: (1) the fractures involved the epiphysis of the distal femur; (2) pathological fractures, open fractures, and comminuted fractures; (3) failed to complete the follow-up. (4) multiple compound injuries; (5) severe craniocerebral injury; (6) open fracture; (7) combined with other lower extremity fractures; (8) combined with other congenital malformations; (9) incomplete follow-up data.

The patient characteristics between the two groups were comparable ($p>0.05$), Table I.

Sample size calculation was performed using the following formula:

$$n = 2 \cdot pq \cdot (Z_{\alpha/2}+Z_{\beta})^2 / (p1-p2)^2$$

This calculation was based on a two-tailed test and a 1:1 sample size ratio between the two groups, indicating an equal number of cases in both groups. For α of 0.05, the two-tailed critical Z value, $Z_{\alpha/2}$, is 1.96. For β, we used Z values of

Table I. Comparison of general information.

Categories	Control group (n=50)	Study group (n=50)	t/χ^2	p
Age, mean (years-old)	6.56±2.04	7.03±1.93	1.183	0.240
Male	14	18	0.735	0.856
Diabetes	27	28	0.040	0.841
Fracture on left side	26	29	0.364	0.546
Gartland fracture type			0.179	0.914
I	22	20		
II	8	9		
III	20	21		
Interval from admission to surgery (h)	14.56±3.19	15.03±2.88	0.773	0.441

1.28 for a power of 0.9 and 0.84 for a power of 0.8, considering a one-tailed test. Although a power of 0.9 is more common and desirable, it necessitates a larger sample size. In this study, $Z_{\alpha/2}$ and Z_{β} are set to 1.96 and 1.28 respectively. The average value of p1 is 0.23, while the average value of p2 is 0.53. q denotes the complementary probability (1-p). In this context, p = 0.29 and q = 0.71. The study's flow chart is illustrated in Figure 1. Given a significance level α of 0.05 and a two-tailed critical Z value, $Z_{0.05} = 1.96$.

Treatment Methods

All operations were performed under general anesthesia. The study group used distal femur 90° locking plate fixation. A lateral incision was made at the distal end of the femur, the skin and subcutaneous tissue were cut through, and the fractured end was exposed through the muscle space. After fracture reduction, a distal femur 90° locking plate was placed with a K wire for temporary fixation. The fracture reduction and the plate placement and attachment were observed by fluoroscopy to prejudge the direction of the distal locking nail and the distance from the epiphysis. The fracture site was secured by using 3 locking screws at the distal end of the fracture and 3 to 4 locking screws at the proximal end of the fracture. The reduction of the fracture and the placement of the plate were observed to ensure adequate fixation. Then, the wound was sutured and bandaged to complete the operation, and the brace was used for external fixation. The control group received K-wire internal fixation combined with external plaster fixation. X-ray fluoroscopy was performed before the operation to mark the distal femoral epiphyseal plate, the position of the fracture end, and the position of the wire. Two assistants continued to traction on both sides of the fractured end. After the fractured end was retracted, the displacement of the fractured end was observed under X-ray fluoroscopy to perform the manual reduction. After fracture reduction, 4 metal bone pins were inserted under fluoroscopy, and the pintails were cut short. Then the wound was closed and bandaged to complete the operation. Plaster was used for external fixation. The wound dressing was changed regularly after the operation, and the children were guided to conduct function exercises to avoid pressure sores.

Postoperative Rehabilitation

After the operation, the patients stayed in the hospital with 10 days of physical therapy with two sessions per day and four days of occupational therapy. Physical therapy consisted of weight-bearing exercises, strengthening exercises, gait training, and aerobic exercise, and functional training progressed gradually based on the individual's functional level. Occupational therapy aimed to train the patients in activities of daily living (ADL) (transfer, sit-to-stand, bed mobility, dressing, self-care retraining, and using adaptive equipment).

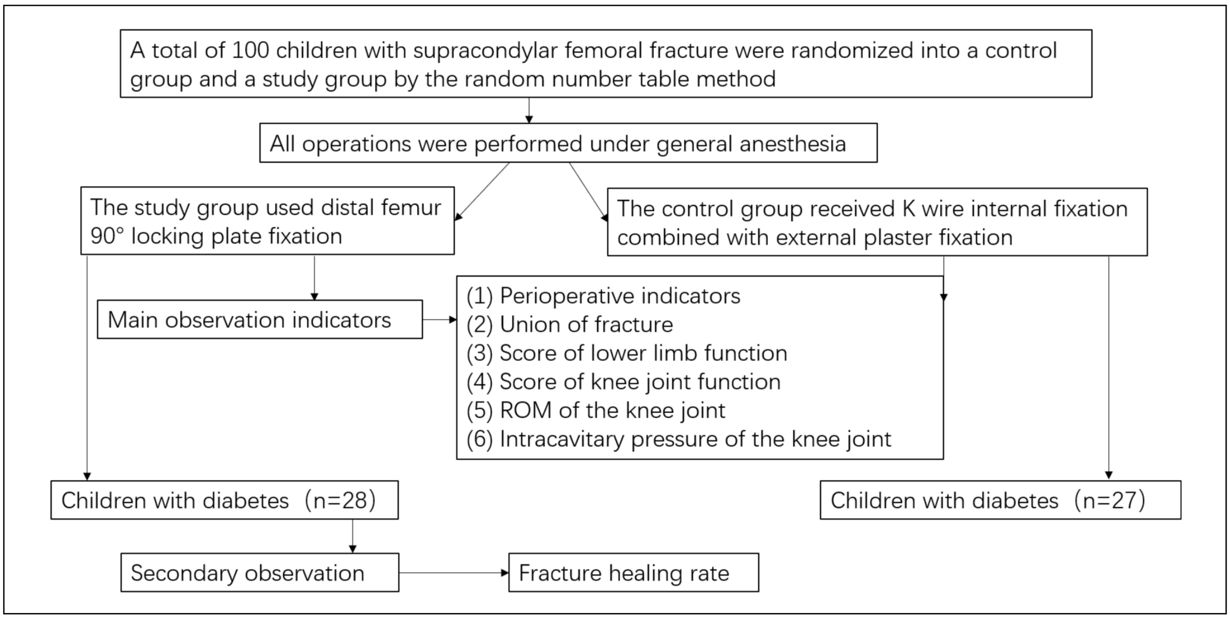

Figure 1. Study flow chart.

The two groups were additionally given Shenjin Decoction: Shenjincao 30 g, Tougucao 30 g, peach kernel 20 g, safflower 20 g, frankincense 20 g, myrrh 20 g, pangolin bead 10 g. Fumigation and washing methods were performed as follows: medicinal materials were soaked in water for 30 minutes and then decocted, 1 dose/d. The decocted medicinal liquid was used in 2 parts, and the medicinal liquid was poured into the fumigation basin, and the patient's knee joint was exposed to the basin, so that the hot air fully fumigated the affected area, and at the same time, a towel soaked in the medicinal solution was applied to the affected area. After the towel cooled, it was replaced, and fumigated for 30 min/time, 2 times/d. Knee exercise rehabilitation was conducted after fumigation.

Outcomes

Primary outcomes

(1) Perioperative indicators. Operation time, intraoperative blood loss, intraoperative fluoroscopy time, and hospital stay. (2) Fracture healing assessment. After surgery, both groups of children underwent X-ray evaluations of the femur's front and side every 4 weeks. This aimed to track fracture healing and their ability to bear weight. Assessment criteria: complete healing: X-rays show continuous bone tissue with no gaps. Partial healing: X-rays show some gaps, indicating ongoing bone growth. No healing: X-rays show significant gaps without evidence of healing. Additionally, weight-bearing ability was evaluated: full: children can walk normally without pain. Partial: children can partly bear weight with minor discomfort. None: children cannot bear weight, potentially needing support. (3) Score of lower limb function. At 28 weeks postoperatively, the Flynn score[10] was used to assess the function of the lower limbs, and it discriminated the function of lower limbs into excellent, good, and poor in terms of fracture angulation, limb unequal length, and pain. Excellent: fracture angle is 0-5°, with an unequal length of limbs within 0-1 cm and no pain. Good: fracture angle is 6-10°, with unequal length of limbs within 1-2 cm and relievable intermittent pain. Poor: fracture angle is over 10°, with an unequal length of limbs over 2 cm and persistent pain. (4) Score of knee joint function. At 28 weeks postoperatively, the Harris-Hip-Score (HHS) score was used to evaluate the knee joint function of the children[11], including pain (30 points), function (22 points), range of motion (ROM) (18 points), muscle strength (10 points), flexion deformity (10 points) and stability (10 points), with a total score of 100 points. The higher the score, the better the knee joint function. At the same time, the knee joint function was graded according to the HHS score, with ≤59 being bad, 60-69 being adequate, 70-84 being good; ≥85 being excellent. (5) ROM of the knee joint[12]. From the 12^{th} week postoperatively, the ROM of the knee joint was measured with a protractor every 4 weeks, and the number of children with a ROM ≥110° was recorded. (6) Intracavitary pressure of the knee joint. At 3 days postoperatively and the last follow-up, the intracavitary pressure of the knee joint was measured. The children were in a supine position with their knees flat. After local anesthesia, a puncture of 2-3 cm was performed at 45° in the upper outer quadrant of the knee joint with a tissue manometer puncture needle (domestic EI-P929 type, Suzhou Yimanjie Medical Devices Co., Ltd., Suzhou, Jiangsu, China), and then a 60 cm-long catheter containing 1/1,000 heparin normal saline and a scanner was connected. After the children were sedated for 5 to 10 minutes, the pressure was measured for 2 minutes, and the mean value was recorded.

Statistical Analysis

The normality of the sample was determined with the Shapiro-Wilk test. Descriptive statistical data were evaluated with the exploratory analyses of the Tukey test. Quantitative mean data (PES/WES: Partial/Whole Exome Sequencing, ISQ: Implant Stability Quotient, and B.L.: Baseline) were assessed with the nonparametric Wilcoxon-Mann-Whitney U test to analyze the inferential statistics.

In this research, the data were processed by SPSS 24.0 software (IBM Corp., Armonk, NY, USA). The research included count data and measurement data. The measurement data was represented by ($\bar{x}\pm s$) and analyzed using a *t*-test. The count data was represented by [n (%)] and analyzed using the χ^2 test. The difference was statistically significant with α=0.05.

Results

Fracture Union Rate

As shown in Figure 2, the fracture union rate of the control group and the study group after 12 weeks were 16% (8/50) and 38% (19/50), respectively; at 16 weeks, were (31/50) and 84% (42/50);

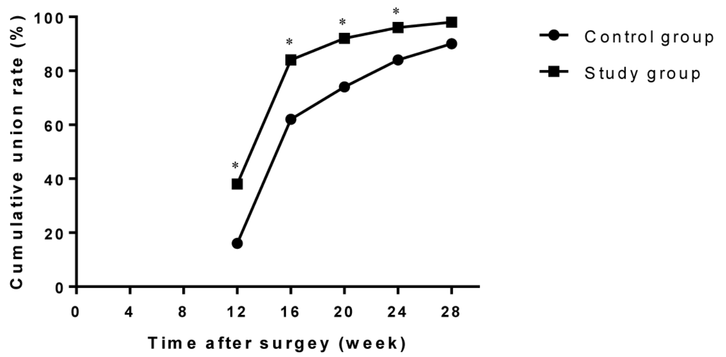

Figure 2. Cumulative union rate of the two groups. The fracture union rate of the control group and the study group after 12 weeks were 16% (8/50) and 38% (19/50), respectively; at 16 weeks were (31/50) and 84% (42/50); at 20 weeks were 74% (37/50) and 92% (46/50); at 24 weeks were 84% (42/50) and 96% (48/50); at 28 weeks were 90% (45/50) and 98% (49/50). The fracture union rate of the study group was significantly higher than that of the control group at 12 weeks, 16 weeks, 20 weeks and 24 weeks after the operation (p<0.05), while the rate showed no significant difference between the two groups at 28 weeks after the operation (p>0.05). *indicated p<0.05

at 20 weeks were 74% (37/50) and 92% (46/50); at 24 weeks were 84% (42/50) and 96% (48/50); at 28 weeks were 90% (45/50) and 98% (49/50). The fracture union rate of the study group was significantly higher than that of the control group at 12 weeks, 16 weeks, 20 weeks, and 24 weeks after the operation (p<0.05), while the rate showed no significant difference between the two groups at 28 weeks after the operation (p>0.05).

Perioperative Indicators

As shown in Figure 3, the operation time of the control group was 77.58±16.84 min, the intraoperative blood loss was 221.5±35.9 cc, the intraoperative fluoroscopy time was 47.2±8.26 s, and the hospital stay was 8.75±1.54 d. In the study group, the operation time was 77.58±16.84 min, the intraoperative blood loss was 233.0±40.8 cc, the intraoperative fluoroscopy time was 45.97±7.69 s, and the hospital stay was 8.55±1.71 d. The two groups showed similar operation time, intraoperative blood loss, intraoperative fluoroscopy time, and hospital stay (p>0.05).

Flynn Classification and HHS Score

As presented in Table II, after treatment, the Flynn classification of the control group included 20 cases of excellent, 18 cases of good, and 12 cases of poor, and the satisfaction rate was 76% (38/50). The Flynn classification of the study group included 24 cases of excellent, 22 cases of good, and 4 cases of poor. The satisfaction rate was 92% (46/50). In Table III, the HHS score of the control group was 76.67±13.84 points, including 22 cases of excellent, 14 cases of good, 11 cases of adequate, and 3 cases of poor, with an excellent-and-good rate of 71% (36/50). The score of the study group was 87.32±15.29 points, including 39 cases of excellent, 7 cases of good, 3 cases of adequate, and 1 case of poor, with an excellent-and-good rate of 92% (46/50). The study group yielded a more favorable outcome concerning the HHS scores, HHS excellent-and-good rate, and Flynn scores satisfaction rate than the control group (p<0.05).

Weight-Bearing Recovery Time and Fracture Union Time

As shown in Table IV, after 12 weeks of follow-up, 38 cases in the control group recovered weight-bearing function, and 31 cases showed a complete union of fractures. A total of 46 cases in the study group recovered weight-bearing, and 42 cases had a complete union of fractures. The study group had a higher 12-week weight-bearing recovery rate and fracture union rate in comparison with the control group (p<0.05).

Recovery Time of ROM of the Knee Joint

For the recovery of knee joint function at 12 weeks, 16 weeks, 20 weeks, and 24 weeks after the surgery, there were 21 cases, 36 cases, 40 cases, and 44 cases in the control group, respectively, and 26 cases, 41 cases, 46 cases, and 48 cases in the study group, respectively. The activity recovery ratio at each time point between the two groups did not come up to the statistical standard (p>0.05) (Table V).

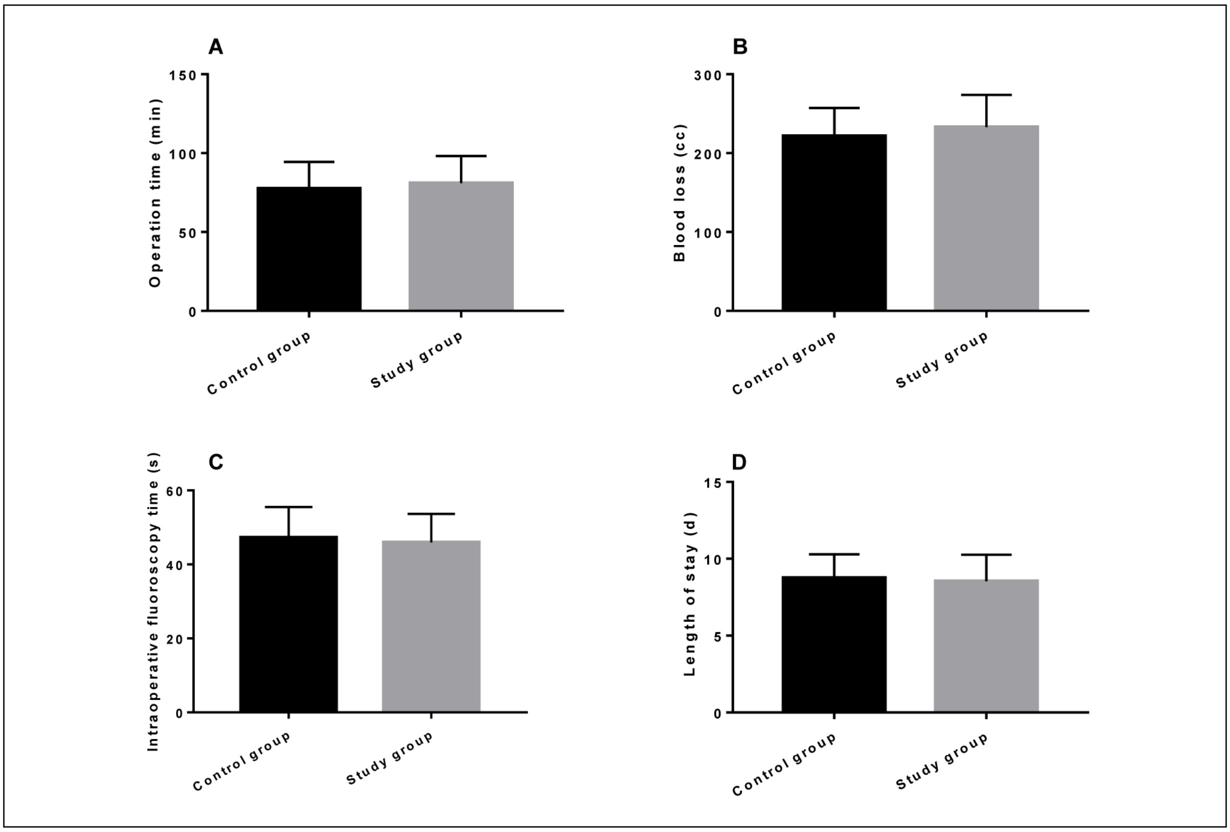

Figure 3. Comparison of the operation time and blood loss. **A**, indicated the operation time of the two groups; (**B**) indicated blood loss in the surgery of the two groups; (**C**) indicated intraoperative fluoroscopy time of the two groups; (D) indicated the length of stay of the two groups. The two groups observed similar operation time, intraoperative blood loss, intraoperative fluoroscopy time, and hospital stay (p>0.05).

Table II. Comparison of Flynn classification after treatment.

Groups	Excellent	Good	Poor	Satisfaction rate (%)
Control group (n=50)	20	18	12	38 (76.0)
Study group (n=50)	24	22	4	46 (92.0)
χ^2				4.762
p				0.029

Table III. Comparison of HHS score after treatment.

Groups	HHS scores ($\bar{x}$±s)	Excellent	Good	Adequate	Poor	Good and excellent rate (%)
Control group (n=50)	76.67±13.84	22	14	11	3	36 (72.0)
Study group (n=50)	87.32±15.29	39	7	3	1	46 (92.0)
t/χ^2	3.652					6.050
p	<0.001					0.013

Intracavitary Pressure of the Knee Joint

As demonstrated in Figure 4, at 3 days postoperatively, the intracavitary pressure of the knee joint of the control group and the study group were 0.72±0.24 kPa and 0.77±0.18 kPa, respectively, 0.64±0.14 kPa and 0.52±0.11 kPa at 8 weeks after the operation, 0.43±0.08 kPa and 0.37±0.07 kPa at 16 weeks, and 0.33±0.06 kPa

Table IV. Comparison of weight-bearing recovery time and fracture union time.

	Time of weight-bearing recovery		Time of fracture union	
Groups	**≤12 weeks**	**>12 weeks**	**≤12 weeks**	**>12 weeks**
Control group (n=50)	38	12	31	19
Study group (n=50)	46	4	42	8
χ^2	4.762	6.139		
p	0.029	0.013		

Table V. Comparison of the recovery time of ROM of the knee joint.

Groups	12 weeks	16 weeks	20 weeks	24 weeks
Control group (n=50)	21	36	40	44
Study group (n=50)	26	41	46	48
χ^2	1.004	1.412	2.590	2.174
p	0.316	0.235	0.108	0.140

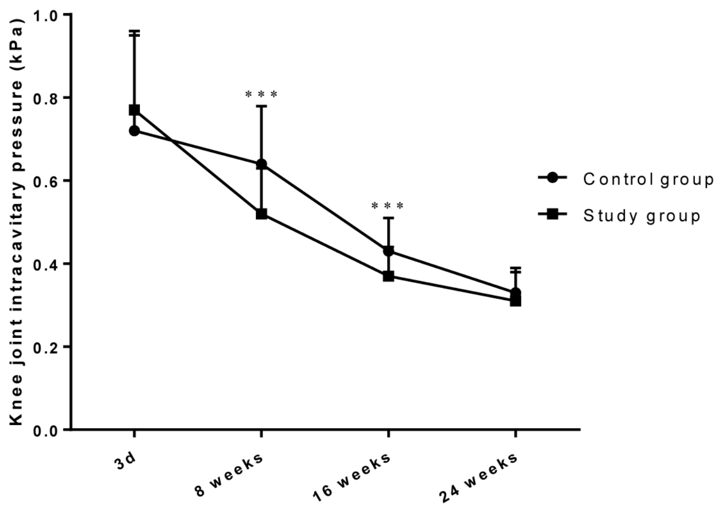

Figure 4. Comparison of intracavitary pressure of the knee joint. At 3 days postoperatively, the intracavitary pressure of the knee joint of the control group and the study group was 0.72±0.24 kPa and 0.77±0.18 kPa, respectively; they were 0.64±0.14 kPa and 0.52±0.11 kPa at 8 weeks after the operation, 0.43±0.08 kPa and 0.37±0.07 kPa at 16 weeks, 0.33±0.06 kPa and 0.31±0.07 kPa at 24 weeks. The intracavitary pressure of the knee joint of the two groups witnessed a gradual decline with time, with lower remarkably lower results in the group with locking plate fixation compared with the group with K wire treatment at 8 weeks and 16 weeks after the surgery ($p<0.001$), and no great differences were detected at 24 weeks after the surgery ($p>0.05$). ***indicated $p<0.001$

and 0.31±0.07 kPa at 24 weeks. The intracavitary pressure of the knee joint of the two groups showed a gradual decline with time, with lower remarkably lower results in the study group compared with the control group at 8 weeks and 16 weeks after the surgery ($p<0.001$), and no great differences were detected at 24 weeks after the surgery ($p>0.05$).

Postoperative Complications

It was clear in Table VI that the control group had 1 case of deep vein thrombosis (DVT), 5 cases of delayed union, 6 cases of joint stiffness, and 1 case of infection, with an overall adverse reaction rate of 32% (16/50). The study group had 3 cases of delayed union, 3 cases of joint stiffness, and 1 case of infection, with an overall

Table VI. Comparison of postoperative complications.

Groups	DVT	Delayed union	Stiffness (Flex<90°)	Infection	Total rate (%)
Control group (n=50)	1	5	6	4	16 (32.0)
Study group (n=50)	0	3	3	1	7 (14.0)
χ^2					4.574
p					0.032

adverse reaction rate of 14% (7/50). Patients experienced fewer postoperative complications after locking plate fixation, as compared to those who received K wire internal fixation ($p<0.05$).

Fracture Union Rate Between Children with Diabetes in the Two Groups

Compared with the control group, the fracture union rate of children with diabetes in the study group was significantly higher at 12 weeks (22.2% *vs.* 50.0%, $p=0.032$), 16 weeks (44.4% *vs.* 75.0%, $p=0.021$), 20 weeks (59.3% *vs.* 89.3%, $p=0.011$) after surgery, respectively. The fracture union rate of diabetic children in the study group was higher than the control group at 24 weeks and 28 weeks, but there were no significant differences between the two groups ($p>0.05$) (Table VII, Figure 5).

Cases of Complications

At 3 months postoperatively, one male child in the study group had pathological changes in the knee joint, including bleeding, edema, and fibrinogen exudation that formed a stiff knee joint. One female child in the control group developed DVT postoperatively due to increased blood viscosity from intraoperative and postoperative blood loss, fluid loss, and soft tissue exudation. This child had reduced preoperative activity, restricted movement of the lower extremities, physiological or organic alterations of the cardiopulmonary and vascular valves, and slowed

Table VII. Comparison of fracture union rate between children with diabetes in the two groups [n (%)].

	12 weeks	16 weeks	20 weeks	24 weeks	28 weeks
Control Group (n=27)	6 (22.2)	12 (44.4)	16 (59.3)	20 (74.1)	23 (85.2)
Study Group (n=28)	14 (50.0)	21 (75.0)	25 (89.3)	26 (92.9)	27 (96.4)
χ^2	4.583	5.347	6.531	3.543	2.103
p	0.032	0.021	0.011	0.060	0.147

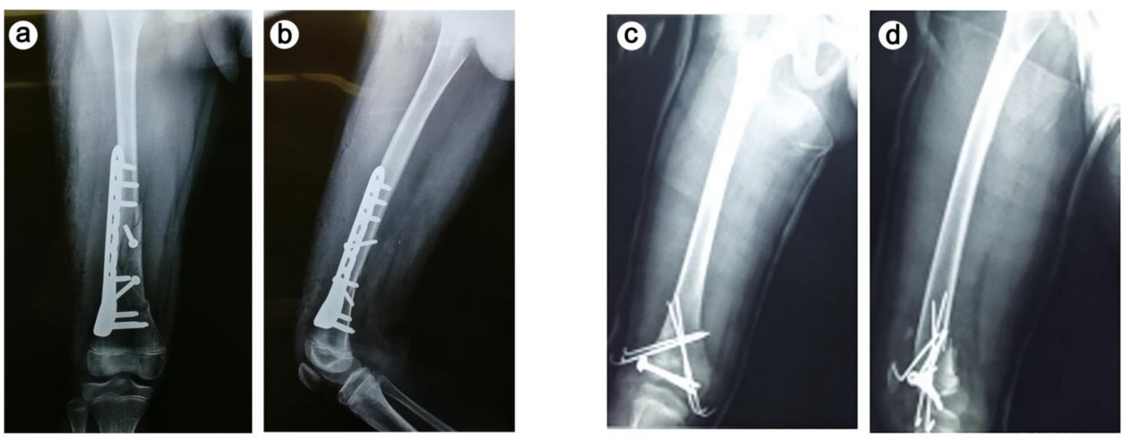

Figure 5. Typical radiographic images of two groups. **a-b**, represent those in the study group who received distal femur locking plate fixation, (**c-d**) represent those in the control group who adopted Kirschner wire (K wire) internal fixation.

venous return, resulting in a relative stagnation of blood flow to the lower extremities.

Discussion

The femoral supratarsal fracture is a fracture within 5 cm above the inner and outer malleolus of the femur, which belongs to the type A fracture in the Muller classification of distal femoral fractures, etc. SFF in children refers to a special type of distal femoral shaft fracture with the fracture line between the femoral condyle and the metaphysis[2]. The unclosed epiphyseal line of the distal femur in children is a mechanical weak point of the lower femur, and the supracondylar part of the femur is the transition point of cancellous and cortical bone, which is the relative mechanical weak point of the distal femur. Therefore, the subjection of the femur to violence may easily give rise to SFF[13]. The epiphyseal area of the distal femur is an important ossification center for the growth of children, accounting for 45% of the length of the lower limbs, and it is prone to developmental abnormalities, lower limb deformities, and dysfunction after injury[14]. Different from adults, femoral supra-ankle fractures in children mainly damage the stem marrow, which is often close to the bone marrow, and bone marrow injury will affect the growth of bone. Even if there is no bone marrow injury, it will stimulate future growth and affect nearby bone marrow. The growth and formation of the medullary plate and diaphysis make it crucial to consider the potential impact of surgery and internal fixation on bone marrow re-injury and future bone development in cases of this fracture type. Internal fixation is required to minimize further damage to the bone marrow. Therefore, the above fixation methods are not suitable for children. In recent years, driven by economic growth, there has been an increase in the incidence of high-energy injuries, such as car accidents. Supracondylar femoral fractures in children often necessitate surgical treatment due to their proximity to the medullary end of the femur and the adjacent knee joint.

The purpose of the treatment of SFF in children is to achieve anatomical reduction, restore the normal length of the lower limbs, correct rotation and axis, and avoid abnormal bone development or developmental disorders. SFF in children is a refractory injury, and previous fixation methods are associated with numerous shortcomings and postoperative complications[15-17]. The methods currently used mainly include K-wire internal fixation, elastic intramedullary nail fixation, and reconstruction fixation. However, in numerous instances, K-wires tend to deform due to their limited fixation strength, resulting in the displacement of the fractured fragments. Elastic intramedullary nail fixation, characterized by the distal medullary cavity's thickness and unstable fixation, can lead to angulation, rotation, and shortening of the fractured ends. Similarly, challenges related to the reconstruction plate fixation or the use of plates for different anatomical regions include intricate plate shaping, suboptimal adhesion, insufficient rigidity, undesirable fixation angles, and a shortage of fixation screws due to epiphyseal interference at the distal end of the plate. In contrast, the application of the distal femur 90° locking plate presents a promising approach for treating children with supracondylar femoral fractures. This approach offers several advantages, including convenient placement, elimination of the need for plate shaping, robust fixation, and a well-engineered biomechanical design[18,19]. In achieving similar clinical outcomes, repositioning operations are extremely demanding as internal fixation with plates is absent in the K wire treatment, so attention is required to the patient's skincare issues prior to extraction of the K wire in phase II, and anti-inflammatory and anti-infective treatments are performed if necessary. For severely comminuted fractures such as intra-articular compression fractures, K-wire fixation alone fails to ensure the strength and high structural stability of the Achilles. At the same time, 90° locking plate fixation can increase bone stability with the superior recovery of long-term joint function *vs.* K wire fixation.

This study used distal femur 90° locking plate fixation to treat SFF in children and achieved favorable results. The fracture union rate of the study group was significantly higher than that of the control group at 12 weeks, 16 weeks, 20 weeks and 24 weeks after the operation, while the rate showed no significant difference between the two groups at 28 weeks after the operation. Compared with the control group, the fracture union rate of children with diabetes in the study group was significantly higher at 12 weeks, 16 weeks, and 20 weeks after surgery. A previous study[20] showed that diabetes compromised the process of bone formation and fracture healing by increasing advanced glycation end-product formation and reactive oxygen species (ROS). In addition, diabetes could alter bone microarchitecture and stimulates osteoclast activity[21]. In the present study, the distal femur 90° locking plate fixation had better efficacy for children with diabetes. The study group yielded a more favorable outcome with regard to the HHS scores, HHS excellent-and-good rate, and Flynn scores satisfaction rate than the control group. Compared with K wire fixation, distal femur 90° locking plate fixation better promotes the union of the fracture. It has been reported[22] that the fixation strength of K wire is insufficient and thus requires external fixation of plaster. Additionally, due to poor compliance, children are prone to irritation of surrounding soft tissues by the needle tail, and the loosening and shedding of K wires are also rather frequent, which hampers the union of fracture. Moreover, percutaneous K wire puncture may damage the epiphyseal plate and epiphysis, and its insertion angle may result in the entrance of the wire into the knee joint, which hinders the postoperative knee joint recovery[23]. The distal femur 90° locking plate cuts a part of the periosteum from the outside of the broken end to achieve anatomical reduction. It has been reported[24] that the integrated screw and the locking plate provide better support and stability, which is conducive to early functional exercise and fracture union, which is consistent with the results of the present study. The intracavitary pressure of the knee joint of the two groups showed a gradual decline with time, with remarkably lower results in the study group compared with the control group at 8 weeks and 16 weeks after surgery, and no great differences were detected at 24 weeks after the surgery, indicating that the distal femur 90° locking plate reduces the intracavitary pressure of the knee joint in the early stage. Studies[25] have pointed out that intracavitary knee hypertension is one of the causes of knee joint pain and seriously compromises the function of the knee joint. The changes in capillary permeability and effusion in the affected knee joint lead to high pressure in the knee joint cavity, which aggravates blood stasis and interstitial edema, forming a vicious circle and seriously hindering the function of the knee joint[26]. The two groups showed similar operation time, intraoperative blood loss, intraoperative fluoroscopy time, and hospital stay. The distal femur 90° locking plate fixation is simple and obviates the need for shaping, with a manageable safety. In addition, it facilitates the early functional exercise and fracture union with a significantly lower incidence of postoperative complications than that of the K wire treatment.

The theory of traditional Chinese medicine believes that fractures can easily cause damage to the muscles, bones, and collaterals, which in turn causes stagnation of qi and blood in the meridians, affecting the normal activities of joints. Shenjincao and Tonggucao in Shenjin Decoction have the functions of dispelling wind and dampness, promoting blood circulation and reducing swelling; peach kernel and safflower can promote blood circulation and remove blood stasis, and relieve pain. To dissipate stagnation, the combination of various drugs can play the role of dredging the stomach, promoting blood circulation, and dredging collaterals[27]. Local fumigation and washing of Shenjin Decoction has the effect of loosening joints and collaterals, promoting blood circulation and relieving pain, and has good effects in the treatment of joint pain, numbness, rheumatism, etc. Shenjin Decoction fumigation and washing assisted knee joint exercise rehabilitation device produces promising results in patients with knee joint stiffness after supracondylar fracture, which can effectively improve knee joint function and reduce complications. The knee joint exercise rehabilitation apparatus is a form of physical therapy that utilizes the body's inherent resilience to gradually restore joint functionality. At the same time, it can be supplemented with Shenjin Decoction to dredge the muscles and collaterals, activate blood and remove blood stasis, and fundamentally solve the patient's knee joint stiffness. This can accelerate the improvement of joint function and reduce complications[28,29].

Notwithstanding, a locked plate might be a reliable option for SFF, but it also features several limitations. The use of locking plates relies on novel mechanical and biological concepts: bone healing is endochondral because of the elasticity of the constructs. Preoperative planning is required to determine the fracture reduction strategy and select the implants. The type of plate and the type of screws and their position determine the mechanical properties of the construct. Failure of locking plate fixation is a new phenomenon that differs from conventional plate fixation. These are brought on by inadequate planning, which is made worse when minimally invasive surgery is performed. Often, the fracture is not reduced correctly (leading to malunion), the implant length is incorrect, or the screw type, number, location, and implantation sequence are inappropriate. Together these can result in an overly rigid construct with poor healing and implant failure or, the opposite, an overly flexible construct that can compromise healing.

However, due to the constraints of many factors, this study still has many deficiencies: 1. In terms of research samples, the sample size collected in this experiment is relatively small, and it is not possible to more comprehensively and objectively evaluate the accurate efficacy. 2. In terms of observation indicators and curative effect judgment, this study adopted more subjective curative effect evaluation standards. There are large differences in subjective feelings among individuals and differences in understanding the questions in the scale, so it is difficult to make an absolutely objective assessment of the scale. 3. In terms of follow-up time, the postoperative follow-up period was short, and the long-term treatment effects could not be well observed.

Conclusions

The distal femur 90° locking plate fixation for diabetic children with SFF obviates the need for plate shaping and ensures firm fixation, with biomechanical design, promising efficacy, and few complications. The distal femur 90° locking plate fixation has better efficacy for children with diabetes. It shows great potential as the treatment of choice for diabetic children with SFF.

Ethics Approval

The study was approved by the Ethics Committee of Cangzhou Hebei Integrated Traditional Chinese and Western Medicine Hospital (LO-PO202180202).

Informed Consent

The informed consent was signed by the patients and their families.

Availability of Data and Materials

All data are available upon request to the corresponding author.

Conflict of Interest

The authors declare no conflict of interest.

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Authors' Contributions

All authors contributed equally to the study.

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