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ORIGINAL PAPER

Clinical outcomes of revision with retrograde intermedullary nailing for failed plating of distal femoral fractures: a retrospective study

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Abstract

Purpose To assess the feasibility and effectiveness of retrograde intramedullary nail (RIN) revision surgeries for locking compression plate (LCP) failure in distal femoral fractures.

Methods This retrospective study included 13 patients who suffered from metalwork failures after they initially underwent open reduction and LCP fixation. In patients who eventually underwent RIN revision from January 2014 to December 2016, range of motion (ROM) and Hospital for Special Surgery (HSS) scores obtained before surgery and at the final follow-up time were analysed.

Results The average operative time was 155 minutes (range, 120–210 minutes), and the average blood loss volume was 650 ml (range, 200–1350 ml). There were two cases of complications (15.38%): one was calf muscle vein thrombosis, and the other was a superficial infection. No deep tissue infection or deep vein thrombosis was observed post-operatively. The average follow-up time was 16 months (range, 12–24 months). All fractures healed in a mean of 6.5 months (range, 4–12 months), and one patient underwent an additional bone graft surgery that did not involve a bone graft during the RIN revision operation (this eventually healed at 12 months post-operatively). The mean ROM before the operation was 86.92 ± 12.34°. At the final follow-up, the mean ROM was 112.69 ± 9.27°. There was a significant difference between pre-operative and post-operative ROM ($P < 0.01$). The mean HSS score improved significantly from 38.85 ± 9.62 points pre-operatively to 79.62 ± 5.42 points post-operatively. There was a significant difference between pre-operative and post-operative HSS scores ($P < 0.01$).

Conclusions RIN revision surgery achieved excellent clinical results in patients with LCP failure.

Keywords Distal femoral fracture · Locking compression plate · Failure, retrograde intramedullary nail · Revision

Distal femoral fractures comprise 4–6% of femoral fractures [1, 2]. The surgical treatment methods used in these patients include retrograde intramedullary nail (RIN) fixation and plate fixation. According to Christian Hierholzer et al. [3], RIN fixation is mainly suitable for extra-articular fractures (AO/OTA 33A) of the distal femur, whereas locking plates are suitable for most distal femoral fractures, including severely comminuted (AO/OTA 33C) and osteoporosis fractures.

The surgical procedure used in locking compression plate (LCP) surgery requires fewer assistant devices than are needed during the less invasive stabilization system (LISS) approach. Thus, LCP surgery has been widely used in some hospitals in China in recent years.

However, LCP treatment has a relatively high incidence of complications, including non-union and metalwork failure, which have become a challenge for surgeons.

In some medical literature reports, the risk factors for non-union and delayed bone union in distal femoral fractures have included the presence of open fracture, medial bone defect,

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and comminuted fracture [4, 5]. A poor blood supply in the distal femur has also been reported to contribute to a higher risk of non-union [6]. Metalwork failures are normally related to non-union and delayed union, but some metalwork failures occur earlier than the normal healing time of fractures.

Considering the higher failure rate of the original use of LCP in clinical practice, the failure rate of the RIN is lower. Based on the experience of RIN used in the primary operation of distal femoral fractures, RIN revision was used for patients with LCP failure.

A retrospective analysis of 13 patients who underwent RIN revision surgery in our hospital due to LCP metalwork failure from January 2014 to December 2016 was performed to assess the feasibility and effectiveness of RIN revision surgery.

Methods

Patients

We reviewed all distal femoral fracture cases treated in our institution between January 2014 and December 2016. The radiographic and clinical data from all the patients were collected and analysed. The inclusion criteria were as follows: (I) patients with distal femoral fracture (within 15 cm of the furthest end of the femur, including condylar fracture and supracondylar fracture) who previously received LCP fixation; (II) the metalwork failed, and the refractures were type A and type C1 and C2, which are suitable for RIN fixation; (III) patients with complete radiological imaging data pre-operatively and post-operatively; and (IV) informed consent was signed by all patients, who authorized the surgical treatment and allowed the use of their clinical data for scientific purposes.

The exclusion criteria were as follows: (I) patients who pre-operatively presented with suspected infectious symptoms and signs or abnormal inflammation markers, such as increased erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP); patients in whom a rapid frozen biopsy specimen examination taken during surgery confirmed purulent inflammation; (II) patients with serious physical diseases and thus a high risk of surgery; and (III) patients with bad flexion function of the knee joint, which bent less than 40°–60°, for whom IMN is difficult to implant.

Operative techniques

The diameter of the isthmus of the medullary cavity is measured on the X-ray before surgery. All surgeries were performed by the same group of surgeons under general anaesthesia. The patients were placed in the supine position on a radiolucent table, and the anterolateral approach was used for the fracture site. First, we sent the suspected infectious tissues for rapid frozen biopsy examination. If pus cells or inflammatory tissues were detected, immediate revision was not allowed, and a bacterial culture was taken to help choose sensitive antibiotics and the next treatment post-operatively. We focused on how to protect the blood supply and then removed the metalworks. Subcortical dissection was conducted to clear away all the scar and hyperplasia tissue between both ends of the fracture with an electrotome. The hardened bone tissue was removed, the medullary cavity was opened, and after the fracture reduced, the fracture position was maintained using spotty reduction forceps. All cases were then treated with RIN, and the knee was flexed to 40° to 60°. A 20- to 30-mm subpatellar incision was adopted, and the patellar tendon was split longitudinally. The patellar tendon was retracted to expose the posterior cruciate ligament, a guide pin was placed in the notch, 1 cm anterior to the ligament insertion on the femur, and the position was verified with fluoroscopy. The nail entry point should be located in the middle of the intercondylar notch on the A-P view and at the anterior tip of the Blumensaat intercondylar roof line on the lateral view. The proximal expanded portion of the nail was then reamed using a short solid reamer. The guide wire was passed into the distal fragment. After serial reaming of the medullary cavity, all loose fragments were irrigated from the joint. An appropriately sized nail (Double medical technology Co., LTD, Xiamen city, Fujian province, People's Republic of China) was inserted by hand, in which the distal tip of the nail ended at the level of the lesser trochanter. After unsatisfactory manipulation outcomes for patients with poor knee joint activity (bent less than 110°), a parapatellar arthrotomy incision was made for the following quadriceps femoris and patellar ligament release surgery. Autologous ilium bone strips or allogeneic bone strips were implanted in the bone defect area. The range of motion of the knee joint was examined and recorded during the operation.

Post-operative treatment

Antibiotics were administered within 24 hours after surgery. Low-molecular-weight heparin sodium was injected subcutaneously for ten–14 days. On the second day post-operatively, all patients were required to initiate physiotherapeutic exercise, which included ankle pump exercise, quadriceps muscle strength training, knee flexion and extension exercise. Non-weight-bearing crutch walking was initiated at six weeks. Partial weight-bearing walking was performed with assistance after the growth of the bridged callus was evident, and full weight-bearing walking was allowed gradually.

Follow-up

All patients were required to undergo follow-up at four, eight and 12 weeks and six, 12, 18 and 24 months post-operatively. Range of motion (ROM) and Hospital for Special Surgery (HSS) knee scores were investigated both pre-operatively and post-operatively.

Statistical analysis

All statistical analyses were conducted using 18.0 SPSS software (SPSS Inc., Chicago, USA). Qualitative variables were calculated as the average, standard deviation and range and compared with theoretical models. The Wilcoxon test was used to analyse pre-operative and post-operative continuous variables, and a P value of < 0.05 was regarded as statistically significant.

Results

Patient demographic data

From January 2014 to December 2016, 13 patients suffering from metalwork failures after initially undergoing open reduction and locking compression plate (LCP) fixation for distal femoral fractures eventually underwent RIN. The patient demographic data are shown in Table 1. The patients (11 males and 2 females) ranged in age from 22 to 63 years old, with a mean age of 45.6 ± 4.0 years. The average duration from LCP fixation to metalwork failure was one–18 months (mean, 8.0 ± 5.5 months). Metalwork failure occurred in 3 patients within one month after surgery, at three months post-operative in one and at six months post-operative in the remaining patient. All cases of fracture occurred when the fracture was not healed. All patients described a high-energy trauma, including four open fractures (2 Gustilo-Anderson type 3A and 2 Gustilo-Anderson type 3B). According to the AO classification, ten fractures were type 33A, three were type 33C, and two of four patients with open fractures were preliminarily stabilized using an external fixator.

Follow-up

The average operative time was 155 minutes (range, 120–210 minutes). The average blood loss volume was 650 ml (range, 200–1350 ml). Only one case required blood transfusion. During the operation, ten patients received autologous bone grafts, two patients received allogeneic bone grafts, and one patient received no bone graft.

There were no severe or deadly complications in this study. There were two cases of complications (15.38%): one of calf muscle vein thrombosis and another of superficial infection. No deep tissue infection, deep vein thrombosis or pulmonary embolism were observed post-operatively. The mean follow-up period was 16 months (range, 12–24 months). All fractures

Table 1 Details of 13 patients: demographics, injury and fracture types and outcomes

Patient no.	Sex/ age (years)	Injury mechanism	AO/ Gustilo type	Interval after LCP surgery (months)	Bone graft (autograft/ allograft)	Union time (months)	Knee flexion (degree, pre-op)	Knee flexion (degree, post-op)	HSS (degree, pre-op)	HSS (degree, post-op)
1	M/30	Fall from height	A1	6	Autograft	4	5–105	0–120	41	75
2	M/51	Fall from height	A3	8	Autograft	6	0–100	5–120	31	87
3	M/22	Traffic accident	A2/3A	11	Autograft	6	0–90	0–120	35	81
4	M/38	Traffic accident	C3/3B	1	None	12	5–80	0–120	25	72
5	M/35	Traffic accident	C1	11	Allograft	5	0–90	10–120	30	77
6	M/51	Fall from height	A1	3	Allograft	6	0–80	0–100	50	84
7	F/57	Fall from height	A2	12	Autograft	5	0–110	0–110	52	89
8	M/55	Traffic accident	A3	6	Autograft	7	0–95	0–110	37	73
9	M/40	Traffic accident	A3	1	Autograft	6	0–80	0–120	54	79
10	F/46	Traffic accident	A3	14	Autograft	5	0–90	0–120	47	82
11	M/63	Fall from height	C1/3B	18	Autograft	9	10–80	10–100	32	78
12	M/54	Traffic accident	A3/3A	1	Autograft	8	0–70	0–120	37	74
13	M/51	Traffic accident	A3	12	Autograft	6	0–80	0–110	30	84

healed in a mean of 6.5 months (range, 4–12 months), and one patient underwent an additional bone graft surgery that did not involve a bone graft during the RIN revision (this case eventually healed at 12 months post-operatively).

Clinical outcomes

The clinical outcome parameters, including ROM and HSS scores before the operation and at the last follow-up, were recorded as shown in Table 1. The mean ROM before the operation was 86.92 ± 12.34°. At the end of the follow-up, the mean ROM was 112.69 ± 9.27°, and the difference was statistically significant ($Z = -3.077$, $P = 0.002$). The mean HSS score before the operation was 38.85 ± 9.62. At the end of the follow-up, the mean joint functional score was 79.62 ± 5.42, and the difference was statistically significant ($Z = -3.183$, $P = 0.001$).

Discussion

Distal femoral fractures account for 4–6% of femoral fractures [2, 7], which typically have a bimodal distribution: in young people, they are usually related to a high-energy trauma; in elderly people, they are normally due to a low-energy trauma [8]. In our study, all cases occurring in patients aged between 20 and 63 years were caused by high-energy injuries. The causes of injury included high-velocity road traffic accidents ($n = 8$) and falls from a height ($n = 5$).

Choice of different internal fixation metalworks

At present, the most common treatment methods mainly include locked plates, such as the less invasive stable system (LISS) and RIN fixation [9]. Different literature [10–13] reported that locking plates such as mini-open dynamic condylar screw fixation (DCS), Synthes 4.5-mm VA-LCP curved condylar plate, combined with minimally invasive plate osteosynthesis (MIPO) technique used for distal femoral fractures achieved excellent result, are a safe and effective implant with a relatively low mechanical failure rate.

However, there is currently no consensus about the best way to treat these fractures. In the United Kingdom (UK), there is no nationally accepted guideline on the best practice for the management of distal femoral fractures [14]. The indications for RIN versus plate fixation in distal femoral fracture treatment depend on many factors: the degree of comminution, coronal plane involvement, bone quality and the distal extent of the fracture. Bridge plating and RIN have similar results in the treatment of extra-articular distal femur fractures. Both methods can be applied to all fractures, with the exception of Gustilo-Anderson Type 3B and C open fractures [15].

A newly designed antegrade interlocking angle-stable intramedullary nail (IAIN), combined with half threaded cancellous screws, can provide stable fixation of intra-condylar fractures. Furthermore, it can also minimize complications and accelerate the fracture union and functional recovery of patients with type-C distal femoral fractures [16].

Treatment methods for metalwork failure or non-union

Methods of definitive treatment involved open reduction and internal fixation (ORIF) revision, medial plating, bone grafting and the use of other biologic materials. Definitive treatment of distal femur non-union after initial treatment with a locking plate had a low rate of success, suggesting that this procedure is ineffective as a definitive treatment for distal femur non-union [17]. Augmentative LCP may be optimal to treat distal femoral non-union after retrograde intramedullary nailing (RIN) [18]. Dual plating of distal femur fractures offers a reliable stable fixation in cases with non-union after failed fixation with single lateral plate [19].

Distal femoral fractures after using a locking plate have a higher non-union rate

According to different reports, the non-union rate of distal femoral fractures ranged from 0 to 34% [4, 20]. Distal fractures had a lower healing rate (86.6% vs. 93.7%) and a higher re-operation rate (13.4% vs 6.1%) than shaft fractures, primarily due to higher rates of mechanical failure [21].

A recent review [22] reported that among 23 articles, the incidence of healing complications ranged from 0 to 32% after using a locking plate, the rate of non-union ranged from 0 to 19%, the rate of delayed unions ranged from 0 to 15%, and the rate of implant failure ranged from 0 to 20%. The authors confirmed that the current combination of locking plate implants with minimally invasive insertion techniques does not guarantee successful fracture repair in all cases. Therefore, the use of locking plates for distal femoral fractures is still debated in the literature because of problems with healing and eventual complications.

Wang MT et al. [23] found that multiple factors potentially contribute to non-union; these include a high BMI, open fracture, comminution, fracture infection, a shorter working length, open reduction and internal fixation, the use of stainless steel plate material, high construct rigidity scores and the use of purely locking screw constructs. These findings may indicate that overly rigid plating constructs contribute to non-union.

Early weight-bearing and medial bone defect were two reasons for failure in our study

We did not discuss the exact reason why the implants failed after LCP fixation in our study, but in our group of cases, all plates failed while the patient was walking with weight-bearing before the fracture healed. Three of these patients suffered implant failure within one month after surgery, one suffered failure at three months post-operative, and the other failures occurred at six months post-operative. All cases of fracture occurred when the fracture was not healed.

Like most surgeons, we recommend that it is not advisable to attempt early weight-bearing exercise [24]. The doctor in this study had also instructed the patient not to walk with full weight bearing until the fracture had healed, but three of the patients obviously did not follow the doctor's order. The rest of the patients suffered from non-union and delayed union when the continuity of the bone structure had not yet been restored, and the stress was therefore concentrated on the eccentrically fixed steel plate. The steel plate was unable to withstand the accumulated stress, and this caused the internal plate to eventually fail.

In a series of 335 distal femur fractures, 64 (19%) had failure with lateral locked plating, and nearly half (30/64) of these failures were associated with planned and staged bone grafting for metaphyseal bone loss [4]. Medial bone defects have been reported as a recognized risk factor. In our study, most cases also had medial bone defects. Therefore, during the revision surgery, autogenous bone grafting or allograft bone grafting was used, and we found this effectively promoted the healing of the fractures. One case without bone grafting still underwent further grafting surgery and was eventually healed.

Intra-operative release and functional recovery

Because the fracture is close to the knee joint, the restoration of the knee ROM and the function of the knee joint are negatively affected [25]. In our study, we propose that on the one hand, fracture injuries occurred due to the destruction of soft tissue, while on the other hand, the femoral quadriceps muscle and the knee joint capsule were heavily damaged due to direct open reduction and internal fixation surgery. These muscles and joint capsules are the biological basis for knee function recovery. These events undoubtedly impair the function of the knee joint. Therefore, we checked the function of the knee joint after the fracture was properly fixed, and manipulation release procedures were performed for patients with poor joint movement (bent less than 110°). For the three patients who still had unsatisfactory results for joint movement, quadriceps and joint capsule release surgery was performed until the joint flexion and extension function were significantly improved. After the operation, quadriceps muscle strength training and knee flexion and extension exercises were emphasized. Eventually, at the final follow-up, all patients had a satisfactory range of movement of the knee.

Relative to other modalities of fixation, RIN surgery is associated with early patient mobilization, high rates of fracture union and low rates of intra-operative complications [26]. In our study, except for one patient who underwent bone graft surgery after 5 months of revision surgery, all other fractures eventually healed, no metalwork failure occurred, and better knee joint function was achieved.

The use of intramedullary nails during revision effectively reduced the risk of refracture and implant failure. First, intramedullary nails have biomechanical advantages due to their proximity to the axis of the femur, which reduces the possibility of plate failure. Second, nail fixation has biological advantages due to the minimal damage caused to the fracture site. Finally, reaming of the intramedullary canal can stimulate the blood supply, thus promoting fracture healing.

As a result, we propose that RIN revision surgery is a demanding salvage technique for some distal femoral fractures.

Limitations of the study

The current research has some limitations. First, this is a retrospective study. Second, the sample size was small, and the follow-up time was relatively short. Third, our study did not have a control group. However, this is a preliminary report, and we will continue this study with a larger sample size and a longer follow-up time to make our data more meaningful.

Conclusion

The failure of distal femoral fractures after surgery is a challenge for orthopaedists. We believe that the use of RINs and bone grafting techniques can promote fracture healing and restore good functional activities.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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