BMC Surgery

RESEARCH Open Access

Comparative study of twin-perforated orthopedic pin with metal cable versus ao tension band wiring in patellar fracture management

Xuewu Chen[1†], Enli Li[2†], Jiaru Chen[1†] and Wei Zhang[1*†]

Abstract

Objective This study aimed to evaluate the clinical effectiveness and biomechanical properties of perforated orthopedic bone pins in conjunction with metal wire for the management of large fragment patella fractures.

Methods This study involved 45 patients with large fragment patella fractures who were treated between January 2017 and December 2022. The patients were assigned to either the observation or control group based on the adopted therapeutic modality. The observation group ($n = 23$) underwent open reduction and internal fixation utilizing perforated orthopedic bone pins and metal wire. The control group ($n = 22$) was treated by open reduction and internal fixation using AO Kirschner wire tension bands. The comparative analysis between the groups included the following metrics: operation duration, bone union time, knee joint functionality, incidence of complications, and stability of fixation.

Results The follow-up period ranged from 6–20 months. Twenty-two patients in the observation group achieved excellent outcomes, and one achieved a good outcome, resulting in a combined excellent and good outcome rate of 100%. The distribution of outcomes in the control group was 18 excellent, three good, and one fair, resulting in a combined excellent and good outcome rate of 95.5%. The observation group, treated with perforated orthopedic bone pins and metal wire, demonstrated superior results in terms of lower complication rates and enhanced fixation stability compared to the control group, which was treated with AO Kirschner wire tension bands. Biomechanical testing revealed the twin-perforated pin group withstood 42% greater peak load ($p < 0.05$) and exhibited 31% less displacement under cyclic loading compared to controls.

Conclusion Both treatment modalities—perforated orthopedic bone pins with metal wire and AO Kirschner wire tension bands—were effective in managing large fragment patella fractures. However, the former treatment modality demonstrated superior overall effectiveness, reduced complication rates, and improved stability of fixation, making it a preferable choice for broader clinical adoption.

Keywords Screw, Cable, Patella, Fracture

[†]Xuewu Chen, Enli Li and Jiaru Chen qually contributed to this work.

*Correspondence:
Wei Zhang
zhangwei123_0@wmu.edu.cn
Full list of author information is available at the end of the article

Introduction

The patella, the largest sesamoid bone in the human body, is frequently involved in limb fractures, accounting for 0.5%–1.5% of the total fracture incidence in clinical settings [1]. Several strategies are available for managing patella fractures, with open reduction and internal fixation using the AO Kirschner wire tension band method being the most prevalent. This technique is favored for its straightforward procedure, economical material costs, robust biomechanical fixation, and favorable clinical outcomes. Nonetheless, the AO Kirschner wire tension band method is associated with several challenges, including the susceptibility of the wire to fatigue loosening or rupture [2], complications in guiding the wire through soft tissues, which often lead to bending, looping, and difficulties in wrapping and knotting, manual tensioning of the wire band, complicating the precision of tension control (excessive laxity fails to serve the purpose of the tension band, whereas excessive tightness risks bone damage), the propensity of the wire to dislodge from the Kirschner wire, stimulation of adjacent soft tissues by the ends of the Kirschner wire and wire joint, potentially leading to bursitis, subcutaneous erythema, and tenderness, and risks of skin penetration, migration, and even ulceration due to loosening and displacement of the Kirschner wire. With technological advances, several internal fixation materials have been developed and incorporated into the management of patella fractures. Research indicated that the combination of perforated orthopedic bone pins and metal wire fixation enhances metal histocompatibility, provides increased stability, reduces loosening, and improves handling in the treatment of patella fractures. [3].

This article provides a comparative evaluation of the clinical effectiveness and biomechanical attributes of perforated orthopedic bone pins combined with metal wire internal fixation versus AO Kirschner wire tension band internal fixation. Furthermore, the clinical utility of the former in treating large fragment patella fractures is assessed.

Methods

General Information

Between January 2017 and December 2022, a cohort of 45 patients with closed, large-fragment patella fractures were enrolled and randomly assigned to either the observation or control group. Randomization was conducted using a computer-generated sequence (Research Randomizer v4.0) with consecutively numbered, sealed opaque envelopes, which had been prepared by an independent research coordinator. The assignment was received by the operating surgeon upon patient enrollment. Table 1 presents a comparison of parameters between the observation and control groups. A comparison of the preoperative general conditions between the two groups of patients revealed no statistically significant differences ($P > 0.05$). As a retrospective study, the inclusion criteria were as follows: large patellar fracture, a time from injury to surgery of 1–7 days, and an age over 20 years. The exclusion criteria included pathological fractures, severe osteoarthritis, contralateral limb fractures, craniocerebral trauma, and open fractures. Based on historical data from our institution, which showed a 25% complication rate with Kirschner wire fixation, it was hypothesized that the novel technique would reduce the risk by 50%. With $\alpha = 0.05$ and $\beta = 0.2$, it was determined that

Table 1 Comparison of parameters between the control and observation groups

Parameters	Group A($n = 23$)	Group A($n = 22$)	Statistical value	P
Gender				
Man	13(56.5%)	13 (59.1%)	$\chi^2 = 0$	1
Female	10 (43.5%)	9 (40.9%)		
Side				
Left	13 (56.5%)	14 (63.6%)	$\chi^2 = 0.3$	0.855
Right	10 (43.5%)	8 (36.4%)		
Age (year)	44.3 ± 11.8	46.5 ± 11.5	t = − 0.63	0.53
Mechanism of injury				
Indirect violence	9 (39.1%)	7 (31.8%)	$\chi^2 = 0.04$	0.841
Direct violence	14 (60.9%)	15 (68.2%)		
Time from injury to surgery (day)	4.3 ± 1.3	4.5 ± 1.3	t = − 0.51	0.61
Classification of patella fractures				
Type I	10 (43.5%)	11 (50.0%)	$\chi^2 = 0.21$	0.902
Type II	12 (52.2%)	10 (45.5%)		
Type VI	1 (4.3%)	1 (4.5%)		

a minimum of 19 patients per group would be required (two-tailed Fisher's exact test). The enrollment of 23 vs. 22 patients exceeded this requirement. The observation group, consisting of 23 individuals, received treatment using porous metal bone nails coupled with metal wire for internal fixation. This group consisted of 13 males and 10 females, with an age range of 27–66 years and a mean age of 44.3 years. Thirteen fractures occurred on the left, and 10 occurred on the right. The duration from the occurrence of injury to surgical intervention ranged from 1 to 7 days, with a mean of 4.3 days. The control group consisted of 22 individuals who underwent treatment using AO Kirschner wire tension band for internal fixation. This group consisted of 13 males and nine females, with an age range of 24–69 years and a mean age of 46.5 years. Fourteen fractures occurred on the left, and eight occurred on the right. The mechanism of injury involved indirect violence in seven cases and direct violence in 15 cases. The time elapsed between injury and surgery ranged from 1 to 7 days, with an average of 4.5 days. Fractures were categorized according to the Rockwood classification as type I (non-displaced fracture), type II (transverse fracture), type III (distal or inferior pole fracture), type IV (non-displaced comminuted fracture), type V (displaced comminuted fracture), type VI (vertical fracture), and type VII (osteochondral fracture), with types I, II, and VI selected for comparative analysis between groups. There were 23 cases in the observation group, comprising 10 cases of type I, 12 cases of type II, and 1 case of type VI. Similarly, there were 22 cases in the control group, including 11 cases of type I, 10 cases of type II, and 1 case of type VI.

Surgical Method

The procedure was performed under spinal anesthesia in the observation group, which utilized perforated orthopedic bone pins and metal wire for internal fixation. The subject was positioned supine, with a tourniquet applied proximally to the patella on the thigh of the affected limb. The knee is flexed to eliminate quadriceps tension before inflating the tourniquet. Sterile disinfection and draping procedures were performed, followed by a longitudinal incision along the midline, anterior to the knee. Sequential incisions of the skin, subcutaneous tissue, and deep fascia facilitated exposure of the patella. The fracture termini were thoroughly exposed, and hematomas were removed from the fracture sites and within the joint cavity. These areas were then irrigated with saline, and any entrapped soft tissue at the fracture termini was meticulously excised. The fracture termini were aligned using reduction forceps and securely fixated. Direct visual and tactile assessments confirmed optimal alignment of the patellar surface and lateral cartilage. Twin perforated orthopedic pins (2.0 mm in diameter) were inserted in parallel and orthogonally to the fracture plane. C-arm fluoroscopy validated the precise alignment and appropriate placement of the orthopedic pins. An orthopedic cable (1.3 mm in diameter) with a singular needle end was obtained from Jiangsu Shuang yang Medical Instrument Co., Ltd. (Jiangsu, China) and threaded through the pin perforations to form a figure-eight configuration anterior to the patella. The cable was subsequently tightened, and a pillow-shaped locking buckle secured its position. Excess cable was excised using cable shears. A stability test was performed to assess the integrity of the internal fixation. The patellar ligament expansion area was meticulously inspected for continuity, and any lacerations were sutured. The site was irrigated with saline, and the incision was sutured in a layered fashion.

The control group underwent treatment with AO Kirschner wire and steel wire tension band (Kirschner wire [2.0 mm in diameter] and steel wire [1.2 mm in diameter]; Shanghai Medical Instruments Co., Ltd., Shanghai, China). Anesthesia, incision repositioning and other operations were consistent with the observation cohort. Twin Kirschner wires (2.0 mm in diameter) were inserted in parallel and orthogonally to the fracture plane. C-arm fluoroscopy validated the precise alignment and appropriate placement of the Kirschner wires. A steel wire (1.2 mm in diameter) was maneuvered beneath the Kirschner wires to form a figure-eight configuration anterior to the patella. The wire was incrementally tightened and knotted adjacent to the ligament at the superior or inferior pole of the patella. A stability test was performed to assess the integrity of the internal fixation. The patellar ligament expansion area was meticulously inspected for continuity, and any lacerations were sutured. The site was irrigated with saline, and the incision was sutured in a layered fashion.

A stability test was performed to assess the integrity of the internal fixation. Stability was evaluated in our study through manual stress testing, conducted under fluoroscopic guidance. Controlled varus and valgus forces, along with anterior–posterior and rotational stresses, were applied to assess the fixation's integrity and its resistance to displacement. Intraoperative range-of-motion testing was also conducted to verify the stability of the construction during knee flexion and extension. One partial tear of the patellar ligament was found in the observation and one in the control group, which were closed intraoperatively using absorbable sutures. The active knee extension and flexion rehabilitation program was delayed by two weeks in both cases. (Fig. 1).

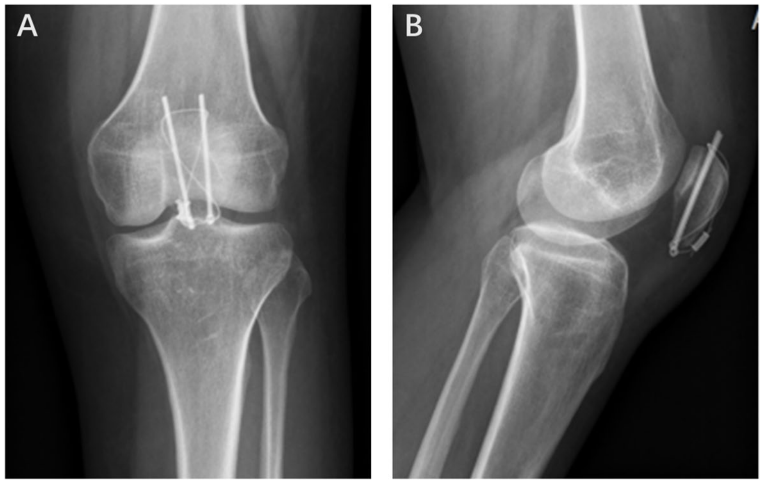

Fig. 1 The tension band was secured with eight turns of knots, followed by tightening using double knots. **A** Postoperative orthopantomogram of the knee joint in the observation group. **B** Postoperative lateral photograph of the knee joint in the observation group (image not modified)

Postoperative treatment

Postoperative wound management involved the application of pressure bandage. Prophylactic antibiotics were routinely administered to mitigate the risk of infection. Functional mobilization of the knee joint, involving incrementally increased flexion angles, commenced on postoperative day 2. No cases of restricted extension were observed. Certain patients received therapy with a continuous passive motion device. The post-surgical protocol required anteroposterior and lateral radiographic evaluations of the knee joint at 3 days, 1 month, 2 months, and 3 months. Subsequent follow-up evaluations were conducted via telephone or outpatient visits at varying intervals.

Statistical analysis

The Shapiro–Wilk test was used to assess the normality of the data distribution. Baseline characteristics of the patients were reported as mean ± standard deviation (SD) and as counts with percentages (n, %). Continuous variables were analyzed using either the Mann–Whitney U test or the t-test, depending on the data distribution. Categorical variables were analyzed using the Pearson Chi-square test or Fisher's exact test. A P-value of <0.05 was considered statistically significant. All statistical analyses were performed using SPSS software (version 27.0; IBM Corp., Armonk, NY, USA).

Clinical outcomes

All 23 subjects in the observation cohort were followed for a period ranging from 6 to 20 months, with a mean follow-up duration of 13.3 months. Radiographic assessments of the knee in anteroposterior and lateral projections indicated that consolidation of the patellar bone occurred within an average of 3.8 months. No incidents of joint pain, stiffness, ankylosis, wound infections, reduction loss, skin perforations, ulcerations, internal fixation loosening or fracture, or patellar bursitis were recorded. The outcomes of the Lu effectiveness evaluation criteria were categorized as follows: excellent, 22; good, 1. Hence, the efficacy rate was 100%.

All 22 subjects in the control group were followed for a period ranging from 6 to 20 months, with an average follow-up duration of 12.9 months. Knee radiographs in anteroposterior and lateral views indicated that patellar bone consolidation occurred within an average of 3.9 months. Postoperative complications included skin irritation, pain, and patellar bursitis in three subjects at the 6-month follow-up; Kirschner wire loosening and displacement in one subject at the 13-month follow-up; and steel wire rupture in one subject at the 14-month follow-up. The outcomes of the Lu effectiveness evaluation criteria were classified as follows: excellent, 18; good, 3; and fair, 1. Hence, the efficacy rate was 95.5%.

Table 2 shows the postoperative follow-up results of both groups. Table 3 compares surgical and bone healing times (in minutes) between the two groups. Table 4 presents knee joint function 6 months post-surgery using the Bostman patellar fracture efficacy score [4]. Table 5 outlines the complications in each group.

Biomechanical study

Specimen materials

Six adult knee joint specimens were provided by the Anatomy Teaching and Research Laboratory of Wenzhou Medical University (age range, 22–59 years; three

Table 2 The follow-up outcomes after surgery for both groups

Parameters	Group A	Group B	Statistical value	P
Surgical time (x ± S)	47 ± 9	46 ± 11	t = 0.33	0.74
Bony healing time (x ± S)	3.8 ± 0.5	3.9 ± 0.5	t = − 0.77	0.44
Knee function 6 months after surgery(Bostman score)				
Excellent or good	23(100%)	21(95.5%)	$\chi^2 = 0.0005053$	0.98
Fair	0	1		
Complication rate				
No complications	23(100%)	17(77.3%)	$\chi^2 = 25.37$	0.001
Loose or broken internal fixation	0	2(9.1%)		
Significant localized pain	0	3(13.6%)		
Loss of fracture reduction	0	0		

Table 3 The surgical and bone healing times

Group surgery time ($\overline{X}$ $\overline{X}$± S) Bone healing time ($\overline{X}$± S)
Group A 47 ± 9 3.6 ± 0.3
Group B 46 ± 11 3.8 ± 0.2

No significant difference based on a *t*-test at a $P > 0.05$

Table 4 The knee joint functions

Group Excellent but Poor Excellent Rate (%)
Group A 22 1 0 0 100
Group B 18 3 1 0 95.5

No significant difference based on the rank-sum test at a $P > 0.05$

Table 5 A comparison of complications

Complications of local pain and fracture reduction caused by internal fixation within the number of cases in the group. The incidence of obvious loss due to detachment or breakage
Observation group 23 00 00 0
Control group 22 2 3 0 22.3

A significant difference was detected based on a χ 2-test at a $P < 0.05$

male and three female; four left and two right). Each specimen included approximately 20 cm of the femur above the knee and 20 cm of the tibia below the knee, with preservation of the quadriceps tendon, joint capsule, patellar ligament, and bony tissues. The specimens were visually inspected and subjected to imaging examinations to exclude degenerative osteoarthritis, osteoporosis, fractures, and other apparent pathological changes. The specimens were sealed in double plastic bags and stored in a freezer at − 20 °C for subsequent use.

Experimental equipment

The materials used in the current study included the following:

1. Perforated metal bone pins 2.0 mm in diameter and metal cables 1.3 mm in diameter (Jiangsu Shuang yang Medical Instruments Co., Ltd., Jiangsu, China).
2. Metal Kirschner wires with 2.0 mm in diameter and steel wires 1.2 mm in diameter (Shanghai Medical Instruments Co., Ltd., Shanghai, China).
3. Type II denture base resin liquid.
4. Methyl methacrylate copolymer powder
5. recision pressure sensor with a rated load of 500 kg and an accuracy of 0.1 kg. An intelligent display instrument (model XMT- 808; Anhui Bengbu Sensor System Engineering Co., Ltd., Anhui, China).
6. NAC Electronic Extensometer from the North Steel Research Institute, model YYU- 10/50.
7. A set of experimental tools and equipment, including an experimental platform, vascular forceps, cloth forceps, pulleys, pulley seats, expansion screws, custom-made tendon clamps, weights, gloves, steel cables, and power supply.

Experimental procedure

Before the experimental protocol, the specimens were removed from cry storage and subjected to a natural thawing process at ambient temperature for 24 h. Subsequently, the specimens were randomly assigned to two cohorts, each consisting of three specimens. The proximal femur and distal tibia of the specimens were embedded in dental tray powder and then secured within specimen clamps. A saber saw was used to transversely section the patella with meticulous care to avoid compromising the integrity of the patellar tendon. Two cohorts were then assigned to different fixation methodologies to fabricate patellar fracture models: perforated orthopedic pins with metal cables, and AO Kirschner wires with steel wire tension bands.

A circular ferrous plate, measuring 2 cm in diameter and 2 mm in thickness, was placed atop the fracture termini. A pressure transducer was then placed over the ferrous plate to ensure the alignment of the transducer's force-sensing nexus with the plate's centroid and to prevent erroneous readings caused by the transducer's force point contacting the patella's irregular surface. Small perforations were drilled at the termini of the fracture line, orthogonal to the fracture plane, and an electronic displacement extensometer was introduced.

The tension band gradually tightened until the fracture separation was visually eliminated. At this point, a force of 15 N was registered for all nine specimens, and the reading of the electronic displacement extensometer was calibrated to zero. As shown in Fig. 2, masses were progressively added to the distal end of the tibia to induce gradual flexion of the knee joint, transitioning from the initial extended position to a 90° angle. The mass was increased in 5-kg increments, with each increment requiring documentation of the mass, pressure transducer readings, and displacement changes at the fracture sites. Prompt data acquisition after load application was essential due to the creep properties of tendons. The loading sequence continued until the displacement extensometer reading reached 1 mm. (Fig. 3).

Results

SPSS18.0 statistical software system was used for data processing. This study was divided into three groups as shown in Table 6. The displacement of the cleft at the fracture end of the patella fracture was all 1 mm. The graphs of tension and displacement distance for different groups of samples are shown in Figs. 4, 5 and 6.

Analysis and discussion

Contemporary management of patellar fractures

The patella plays a critical role in knee joint functionality, acting as a fulcrum within the extensor mechanism and increasing the lever arm of the quadriceps muscle, thereby improving force transmission and amplification. Patellar fractures primarily result from direct or indirect trauma. The main objective in managing these fractures is the restoration of extensor mechanism continuity and integrity. Surgical intervention for lower pole patellar fractures aims to reconstruct the extensor apparatus, ensure stable fixation, and facilitate the early initiation of knee joint flexion and extension exercises to prevent post-traumatic arthrosis and joint stiffness [6–8]. Several surgical techniques are available for the management of patellar fractures, including Kirschner wire and steel wire tension bands, patellar claws, wire cerclage, hollow compression screws, cable-pin systems, and percutaneous screws via arthroscopy. However, simple wire ring ligation is unable to overcome the tension on the anterior side of the patella when the knee is flexed. As a result, the

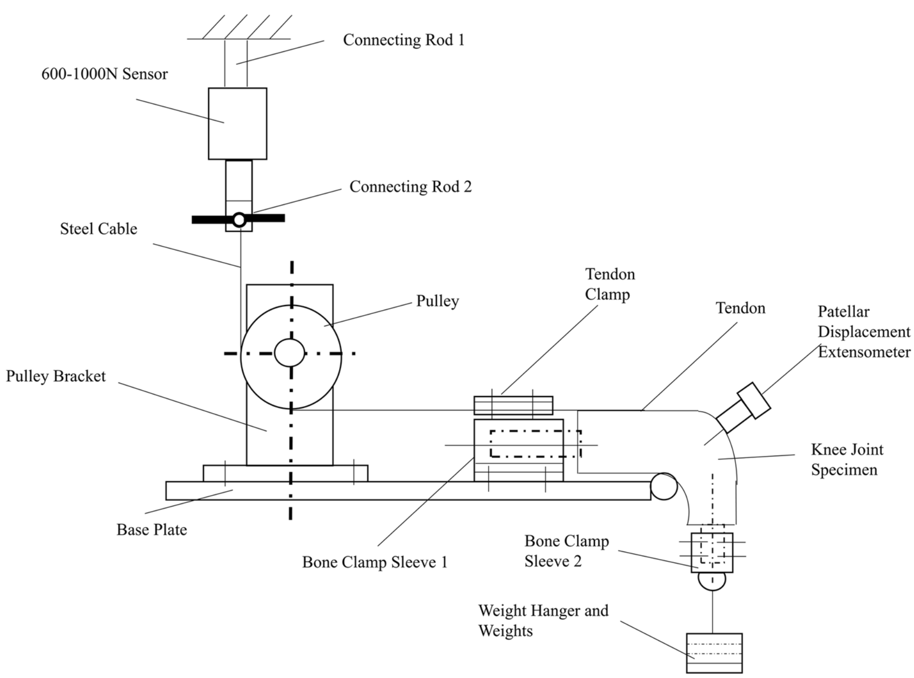

Fig. 2 Experimental set-up for biomechanics of the knee joint (customized to Bernd Schnabel et al. mechanics research set-up) [5]

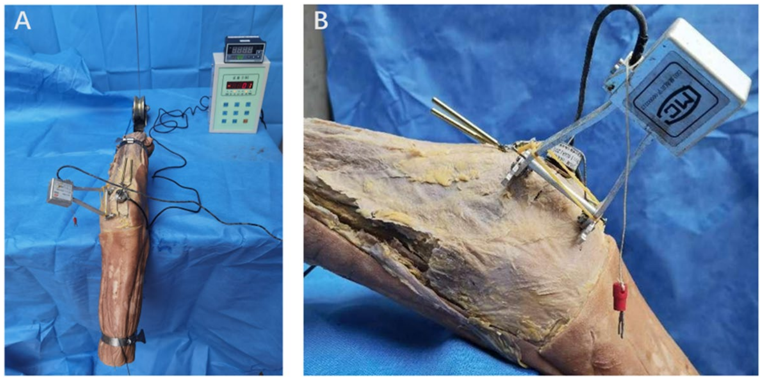

Fig. 3 **A** Physical experiment diagram. **B** Physical experiment diagram (unmodified)

Table 6 Experimental grouping

Groups	Displacement of the cleft (mm)	Patellofemoral forces (N)
AO Kirschner wire and steel wire tension band	1	419 ± 40
Perforated Kirschner Needle Combined Wire Tension	1	482 ± 42
Perforated Kirschner Needle Combined metallic cable	1	529 ± 39

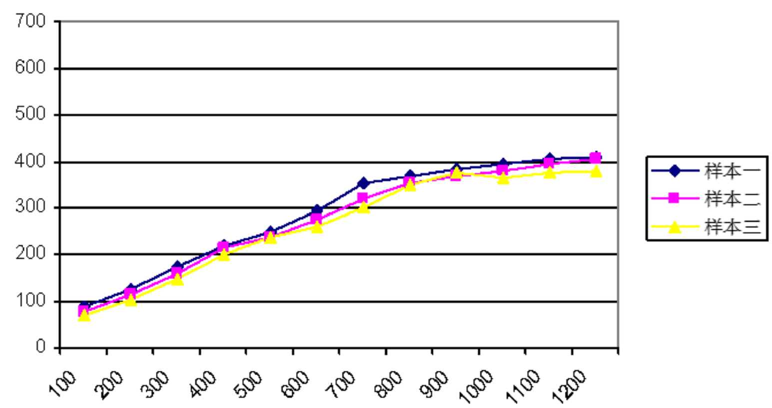

Fig. 4 AO Kirschner wire and steel wire tension band (The horizontal axis shows the displacement of the cleft in μm. The vertical axis shows the patellofemoral forces in N.)

fracture is easily displaced, and this technique is now primarily used as an adjunct to other surgical procedures. Repositioning fixation techniques, such as patellar claws and internal plate fixation, involve large trauma surfaces, and the protrusion of fixation materials through the skin surface causes discomfort for the patient. Empirical studies have confirmed that internal fixation with Kirschner wire and steel wire tension bands remains the primary and most effective strategy for managing patellar fractures. [9–11]. Despite the effectiveness of internal fixation with Kirschner wire and steel wire tension bands, this approach has several drawbacks, including the loosening, migration, and displacement of Kirschner wires, skin and soft tissue irritation from unbent wire ends causing bursitis, subdermal tenderness, and potential skin perforations that could lead to infections. Furthermore, steel wire is prone to metal fatigue, loosening, migration, and fracturing [2], bone intrusion, and joint irritation at anchor sites, all of which may cause pain. Additionally, the tendency of the wire to bend and form loops during tissue traversal complicates the circling and looping process. To address these limitations, the

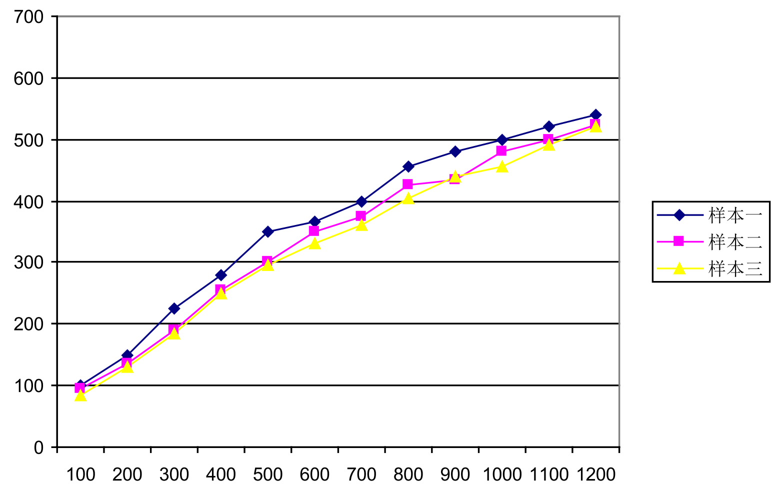

Fig. 5 Perforated Kirschner Needle Combined Wire Tension (The horizontal axis shows the displacement of the cleft in µm. The vertical axis shows the patellofemoral forces in N.)

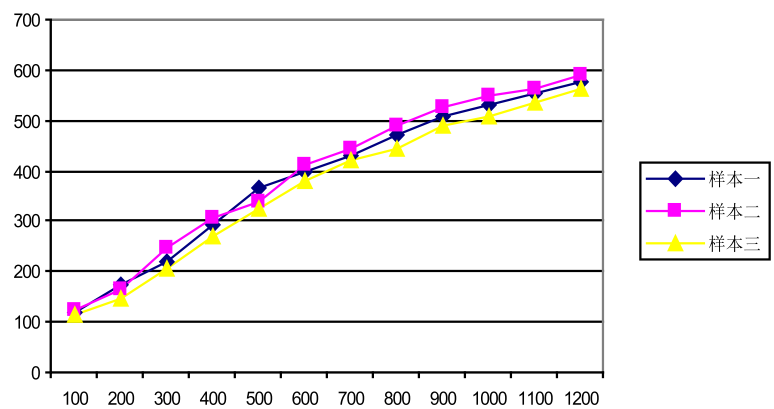

Fig. 6 Perforated Kirschner Needle Combined metallic cable (The horizontal axis shows the displacement of the cleft in µm. The vertical axis shows the patellofemoral forces in N.)

present study employed perforated orthopedic bone pins in combination with metal cables for internal fixation to repair extensive patellar fractures. Clinical and biomechanical studies have endorsed this technique due to its reduced clinical complications and superior biomechanical fixation stability compared to the AO Kirschner wire and steel wire tension band fixation. Previous studies have also demonstrated that perforated orthopedic pins with metal cables result in a higher fracture healing rate, improved knee function, and lower complication rates compared to AO tension band wiring [10–12].

Experimental characteristics and surgical implications

The observation cohort was treated using perforated orthopedic bone pins paired with metal cables for the internal fixation of extensive patellar fractures. The attributes of perforated orthopedic bone pins (2.0 mm in diameter) are as follows: 1. Composed of titanium alloy, which ensures optimal tissue compatibility; 2. The bone pins exhibit substantial strength and ductility, resisting bending and fracture; 3. The metal cable is integrated through the bone pin round holes to consolidate the two elements and reduce the risk of loosening or migration; and 4. The rounded head of the bone pin minimizes trauma to adjacent soft tissues and reduces the risk of skin perforation. The properties of the metal cable (approximately 1.3 mm in diameter) are as follows: 1. The metal cable is constructed from multiple titanium alloy strands, which significantly enhance its resilience and strength, and minimize metal fatigue and fracture risks. The fatigue resistance of a metal cable of equivalent diameter is 9–48 times higher than that of steel wire, with a tensile strength 3–6 times greater than steel wire [13]. 2. The metal cable exhibits commendable tissue compatibility, causing minimal irritation to adjacent soft tissues and the patella. 3. The metal cable has a stable metallic composition and is fabricated from identical titanium alloy material to reduce the probability of electrolytic reactions. 4. The metal cable is aligned with the biomechanical principles of tension bands, translating tension into compressive forces at the fracture sites as the knee joint progressively flexes from an extended posture, thus fostering fracture consolidation. The control cohort was treated using AO Kirschner wire and steel wire tension bands for the internal fixation of extensive patellar fractures.

The management of extensive patellar fractures using perforated orthopedic bone pins paired with metal cables offers several advantages, including adherence to biomechanical design principles, simplicity in execution, secure fixation, reduced complication rates, and the early initiation of knee joint functional exercises. During the surgical intervention, the following considerations must be prioritized:

1. Judicious case selection was important. This modality was predominantly appropriate for transverse, longitudinal, or substantial fractures situated at the patella upper or lower pole.
2. Ideally the optimal surgical window was within 6 h post-injury, prior to the onset of knee joint edema or during the 3–7 days post-injury timeframe following the diminution of knee joint swelling.
3. The internal fixation apparatus was suitable and included perforated orthopedic bone pins (2.0 mm in diameter) and titanium alloy cables (1.3 mm in diameter).
4. The risks of slippage and loosening were considerably mitigated due to the cohesive design of the perforated orthopedic bone pin and the metal cable. Consequently, only a 5-mm segment of the Kirschner wire tail should be left unobscured to minimize cutaneous irritation. Statistical evidence indicated that maintaining the exposed needle tail below 8 mm on the superior bone segment and 6 mm on the inferior segment effectively circumvented this complication.
5. Given the pre-fractured nature of Kirschner wires, the diameter at the pre-fractured junction was diminished, and inadvertent handling could precipitate breakage. Thus, applying excessive bending force to the Kirschner wire during drilling was inadvisable.
6. In affixing the metal cable in a figure-of-eight configuration atop the patella, the metal cable should closely adhere to the bone surface, thereby exerting horizontal compression on the fracture termini when the knee joint was extended.
7. The acute terminus of the metal lock buckle ought to be oriented towards the bone surface to lessen soft tissue irritation.
8. Accurate utilization of specialized instruments for the metal cable and lock buckle.

Constraints

This study has the following limitations: First, the insufficient follow-up time. The average follow-up duration for both groups was approximately 13 months, which was inadequate for assessing joint degeneration, implant durability, and long-term complications [14–16]. Secondly, patient selection bias: a high proportion of young patients may have led to an overestimation of efficacy. Third, in vitro biomechanical testing failed to simulate dynamic muscle loading. Fourth, this study was necessarily unblinded due to the visible nature of the surgical interventions, which may have introduced bias in the assessment of outcomes. However, all radiographic evaluations were conducted by two independent musculoskeletal radiologists who were unaware of the treatment allocation, in order to mitigate this limitation. Lastly, the small sample size and limited study size restricted patient subgroup analyses. It is recommended to expand the sample size in subsequent studies to reduce patient selection bias, address the differences between in-group and out-group patients, extend the follow-up period to 3–5 years, record long-term complications (e.g., the incidence of traumatic arthritis and the rate of secondary surgery), and perform MRI assessments of the knee joint every six months to evaluate the degree of cartilage degeneration. This will help assess the long-term efficacy of the procedure and improve the study's credibility.

The management of extensive patellar fractures with perforated orthopedic bone pins and metal cables is subject to the following limitations: 1. It is unsuitable for fractures of the upper and lower poles of the patella, as well as for severe comminuted fractures. It is only applicable to transverse or longitudinal fractures of the patella, mild comminuted fractures, or large fractures of the upper or lower poles. This limitation may result in significant interference with experimental outcomes. 2. The internal fixation materials are significantly cost-prohibitive. The material cost of AO Kirschner wire tension bands is approximately 1,000 RMB, while the cost of perforated orthopedic bone pins with metal wire is approximately 4,000 RMB, making the latter about 3,000 RMB more expensive than the former. 3. Third, a secondary surgical procedure is required for the removal of the internal fixation device.

Postoperative functional rehabilitation

External fixation was not required for either patient cohort postoperatively. Prompt initiation of functional exercises was imperative for the recuperation of knee joint functionality. It was typically advised that knee joint flexion and extension movements be started in bed on day 2 postoperatively, with select patients also utilizing continuous passive motion training to prevent joint rigidity. Two weeks postoperatively, patients may begin partial weight-bearing ambulation, progressively increasing the weight-bearing contingent on radiographic review outcomes. Ordinarily, full weight-bearing ambulation was feasible 8 – 10 weeks postoperatively, with the resumption of routine activities following bone consolidation.

In conclusion, both the management of extensive patellar fractures using perforated orthopedic bone pins paired with metal cables and the AO Kirschner wire and steel wire tension band fixation demonstrated commendable clinical efficacy. This clinical experimental investigation employed the former technique to address the limitations inherent in AO Kirschner wire and steel wire tension band fixation. Extensive clinical effectiveness was demonstrated with a reduced complication spectrum and enhanced biomechanical stability. Alignment with mechanical principles and promotion of early functional rehabilitation facilitated the management of extensive patellar fractures using perforated orthopedic bone pins paired with metal cables, which has emerged as an optimal surgical strategy.

Acknowledgements
Not applicable

Authors' contributions
Xue-wu Chen: Conceptualization, Data curation, Formal analysis, Writing-original draft. En-Li Li and Jia-Ru Chen: Formal analysis, Methodology, Data curation. Jia-Ru Chen: Validation, Visualization, Data curation. Wei Zhang: Validation, Resources.

Funding
Not applicable.

Data availability
The authors confirm that the data that support the findings of this study can be found within the article. Raw data that support the study findings can be obtained from the corresponding author, upon reasonable request.

Declarations

Ethics approval and consent to participate
The study was conducted in accordance with the guidelines and was approved by the Ethics Committee of Wenzhou Central Hospital (K2021-04–027). The Ethics Committee of Wenzhou Central Hospital waived the need for informed consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]The Dingli Clinical College of Wenzhou Medical University(Wenzhou Central Hospital), Zhejiang Province 325027, Wenzhou, China. [2]Department of Orthopedic, The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University, Wenzhou 325000, China.

Received: 22 September 2024 Accepted: 11 April 2025
Published online: 24 April 2025

References

1. Galla M, Lobenhoffer P. Patella fractures. Chirurg. 2005;76:987–97.
2. 任玉猛, 王红玉, 韩广普, 高宪忠 (2009) 髌骨骨折克氏针钢丝张力带固定技术的改进及疗效观察. 中国骨与关节损伤杂志 24:542
3. 郁新建, 殷吉强, 卢海丹, 吴洁石, 薛骏, 徐瑞生 (2018) 带孔克氏针缆索系统与克氏针张力带固定治疗髌骨下极骨折的疗效比较. 中国骨科临床与基础研究杂志 10:275–279
4. (2003) 《骨与关节损伤和疾病的诊断分类及功能评定标准》己经出版. 中国骨肿瘤骨病 224
5. 张小东 钟, 汪伟,陈日景,高质钢,范少地 (2003) 改良张力带钢丝内固定术治疗髌骨粉碎性骨折. 解剖与临床 157–158
6. Siljander MP, Vara AD, Koueiter DM, Wiater BP, Wiater PJ. Novel Anterior Plating Technique for Patella Fracture Fixation. Orthopedics. 2017;40:E739–43.
7. Oh H-K, Choo S-K, Kim J-W, Lee M. Internal fixation of displaced inferior pole of the patella fractures using vertical wiring augmented with Krachow suturing. Injury-International Journal of the Care of the Injured. 2015;46:2512–5.
8. 王军, 陶晓冰, 张楠, 郜顺兴, 刘晓慧, 崔国胜 (2016) 克氏针钢丝张力带联合缝扎固定治疗髌骨下极粉碎骨折. 中国骨与关节损伤杂志 31:811–813
9. Lefaivre KA, O'Brien PJ, Broekhuyse HM, Guy P, Blachut PA. Modified tension band technique for patella fractures. Orthopaedics & Traumatology-Surgery & Research. 2010;96:579–82.
10. Chang C-H, Shih C-A, Kuan F-C, Hong C-K, Su W-R, Hsu K-L. Surgical treatment of inferior pole fractures of the patella: a systematic review. J Experiment Orthop. 2023;10:58.
11. 广磊李, 平刘,. 髌骨骨折手术治疗方式的研究进展. Chin J Reparat Reconstruct Surg. 2021;35:1057.
12. 邓德礼, 徐晖, 肖立军, 陈文贵 (2015) 空心螺钉张力带钢丝内固定治疗髌骨骨折疗效分析. 中国实用医药 10:69–71
13. Cekin T, Tukenmez M, Tezeren G. Comparison of three fixation methods in transverse fractures of the patella in a calf model. Acta Orthop Traumatol Turc. 2006;40:248–51.
14. Machrowska A, Karpiński R, Maciejewski M, Jonak J, Krakowski P, Syta A. Multi-Scale Analysis of Knee Joint Acoustic Signals for Cartilage Degeneration Assessment. Sensors (Basel). 2025;25(3).
15. Machrowska A, Karpiński R, Maciejewski M, et al. Application of Recurrence Quantification Analysis in the Detection of Osteoarthritis of the Knee with the Use of Vibroarthrography[J]. Adv Sci Technol Res J. 2024;18:19–31.
16. MACHROWSKA A, KARPIŃSKI R, MACIEJEWSKI M, et al. Application of eemd-dfa algorithms and ann classification for detection of knee osteoarthritis using vibroarthrography[J]. Appl Comput Sci. 2024;20(2):90–108.

Publisher's Note