

# "Net cage" technique in the treatment of inferior pole patella fracture: a novel patella internal fixation technique

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## Research article

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# Abstract

## Objective

Fractures of the inferior pole of the patella can cause the knee joint extensor mechanism disorder. The fracture fragments are usually small and comminuted. Therefore, there are certain difficulties in fixation. The purpose of this study is to observe the effect of the "Net cage" technique in the treatment of the inferior pole of the patella.

## Methods

This is a retrospective study that included 16 cases of inferior patella fractures (AO/OTA 34-A1) who underwent the "Net cage" technique from March 2017 to June 2020. Collecting their medical records and follow-up results, measuring indicators include the surgical complications of the fixation method, knee joint function, the number of fluoroscopies, fracture healing, and the incidence of soft tissue stimulation.

## Results

The fractures of all patients healed smoothly, and there were no complications such as failure of internal fixation and fracture of implants. The average number of intraoperative fluoroscopy was 5.56 times (range: 4-10 times); the average fracture healing time was 10.5 weeks (range: 8-14 weeks) ). No patients reported internal fixation-related soft tissue irritation. At the last follow-up, the knee function showed that the average ROM was 133.75° (range: 120°~140°); The average Bostman score was 27.94 points (range: 24-30 points).

## Conclusion

"Net cage" technology for the treatment of inferior pole fractures of the patella has the advantages of reduced fluoroscopy, fixation and stability, early functional exercise, and better knee joints after surgery.

## Introduction

Fractures of the inferior pole of the patella account for about 20% of all patella fractures undergoing surgical treatment<sup>[1]</sup>, and are usually caused by direct trauma to the bent knee joint<sup>[2]</sup>. Like other types of patella fractures, the purpose of surgery for inferior pole fractures is to rebuild the extensor mechanism while restoring the stability of the articular surface<sup>[3]</sup>; the difference is that the fragments of inferior pole fractures are small and comminuted, making it difficult to maintain reduction and fixation<sup>[4-6]</sup>. In order to better fix the inferior pole fracture, many new fixation methods have been developed, including suture fixation, steel plate fixation, and plate combined with tension band fixation<sup>[7-9]</sup>. In addition, A partial

patellectomy with repairment of the patella ligament and anchor suturing has been used as a method for comminuted distal pole fractures<sup>[9, 10]</sup>, but its effectiveness has not been widely recognized.

Tension band wiring technology can convert the anterior tension forces produced by the extensor mechanism and knee flexion into compression forces at the articular surface. It is widely used in the fixation of patella fractures. However, for comminuted inferior pole fractures, traditional tension band wiring technology may not be able to effectively fix it<sup>[6]</sup>. In order to solve these problems, we proposed a novel patella internal fixation technique: "Net cage" technique. The following is a report of the surgical results.

## Patients And Methods

This is a retrospective study. From March 2017 to June 2020, a total of 236 patients with patella fractures underwent surgical treatment were admitted to the Hong Hui Hospital of Xi'an Jiaotong University, 28 cases of (AO/OTA 34-A1) type, of which 5 patients underwent partial patella resection or other surgical treatments were excluded; 4 patients with femoral or tibial fractures that may affect the function of the knee joint were excluded; 3 patients did not complete sufficient follow-up and were excluded except. In the end, 16 patients underwent "Net cage" technique surgery and completed at least 12 months of follow-up. Their demographic characteristics, injury mechanism, and fracture characteristics are as follows (Table 1): Among the 16 patients, there were 11 male, 5 female; their age ranged from 32 to 57 years, with an average of 41.507.39 years; 12 patients were injured by falls and 4 patients were injured by traffic accidents. This study was approved by the ethics committee of the Hong Hui Hospital affiliated to Xi'an Jiaotong University, and all patients signed an informed consent form.

All patients underwent thorough preoperative assessments including standard knee X-rays, computed tomography (CT) scanning, and three-dimensional reconstruction to assess the degree and classification of fracture. In the 16 patients included in the study, the average length of the inferior pole fracture was 10.8mm (7.5~13.7). All patients were performed by doctor Ming Li.

Table 1  
Patient demographics and clinical outcomes

| Patient | Age(year) | Sex    | Average length of inferior pole fracture fragment(mm) | Perspective times | Union time(weeks) | ROM(°) | Bostman score |
|---------|-----------|--------|---|-------------------|-------------------|--------|---------------|
| 1       | 40        | Male   | 7.9   | 10                | 8                 | 0-135  | 28            |
| 2       | 32        | Female | 8.8   | 5                 | 12                | 0-140  | 28            |
| 3       | 38        | Female | 11.3  | 4                 | 12                | 0-135  | 28            |
| 4       | 41        | Male   | 12.5  | 6                 | 10                | 0-140  | 30            |
| 5       | 42        | Female | 10.9  | 7                 | 10                | 0-120  | 30            |
| 6       | 33        | Male   | 13.4  | 6                 | 12                | 0-125  | 27            |
| 7       | 57        | Male   | 13.7  | 5                 | 12                | 0-135  | 28            |
| 8       | 47        | Female | 7.5   | 4                 | 8                 | 0-140  | 28            |
| 9       | 50        | Male   | 13.1  | 4                 | 14                | 0-135  | 27            |
| 10      | 52        | Female | 11.2  | 5                 | 12                | 0-130  | 24            |
| 11      | 33        | Male   | 10.5  | 8                 | 10                | 0-140  | 27            |
| 12      | 34        | Male   | 8.4   | 6                 | 10                | 0-130  | 30            |
| 13      | 38        | Male   | 9.6   | 5                 | 8                 | 0-135  | 28            |
| 14      | 37        | Male   | 9.8   | 4                 | 8                 | 0-135  | 27            |
| 15      | 44        | Male   | 11.2  | 4                 | 10                | 0-125  | 27            |
| 16      | 46        | Male   | 12.4  | 6                 | 12                | 0-140  | 30            |

## Surgical Technique

The patient was placed in a supine position under general anesthesia, antibiotics were used prophylactically, and then a tourniquet was placed on the base of the patient's thigh. The pressure of the tourniquet was 300mmHg. Surgical incisions are selected from the anterior median longitudinal incision of the knee joint, and the skin, subcutaneous tissue, and superficial fascia are cut layer by layer to remove blood clots between the fractures, avoiding the peeling of the prepatellar fascia and periosteum to prevent the separation of comminuted fractures.

After the fractured end is revealed, three 1.8mm bone spicules were driven parallel from the subchondral bone area of the fracture section to the upper pole of the patella (Fig. 1a-1c, during this process, you can directly touch the articular cartilage surface of the patella with your hands to assist in determining the

position of the bone spicule). Use Bone tenaculum to maintain the reduction of the fracture of the inferior pole of the patella and pass the 3 bone spicule retrogradely out of the patella ligament, so that the bone spicule is supported under the bone block of the inferior pole in a row of needles (Fig. 1d), bend the tail of the bone spicule at the upper pole of the patella for 180 °, pull down the bone spicule, and buckle the hook end of the bone spicule at the upper pole of the patella into the quadriceps femoris tendon, and then use two steel cables or steel wires to cross in pairs to fix the fracture in a “net cage” technique(Fig. 1e). Re-check the reduction of the fracture through the C-arm fluoroscopy (Fig. 1f) and flex the knee to check the stability of the inferior pole fracture. After confirming satisfaction, the drainage tube is left in the wound, and the wound is closed layer by layer.

There is no need to wear a brace or protective device after the operation. Patients are encouraged to perform early functional exercises and assist the patients to perform functional exercises through the CPM machine. X-rays are reviewed every month after the operation to understand the healing of the fracture. After the fracture has healed, for patients who have a strong request to remove the internal fixation, we only need to cut the upper part to expose the wire cable tightening device or wire knot and remove the bone spicule, so we need to pay attention to the placement of the wire cable tightening device or wire knot on the upper part of the patella.

## Outcomes Measures

The primary results of this study were surgical complications of fixation methods (fixation failure/displacement, implant fracture/dislocation) and knee function. Secondary outcomes included the number of fluoroscopies and the incidence of soft tissue irritation.

All patients were followed up regularly at the 4th week and every month. During the postoperative follow-up, the anterior and posterior X-rays, lateral X-rays, and knee function were examined. Knee function was assessed by knee range of motion (the patient was instructed to lie prone on the checklist with a standard goniometer to measure ROM) and the Bostman score at the last follow-up. The criteria for fracture healing include clinical manifestations (no pain, no tenderness, and the ability to walk independently without the aid of tools) and radiology (trabecular connection of the two main fragments).

## Results

A total of 16 patients were enrolled in this study. The fractures of all patients healed smoothly, and there were no complications such as failure of internal fixation and fracture of implants. The average number of intraoperative fluoroscopy was 5.56 times (range: 4-10 times); the average follow-up time of patients was 14 months (range: 12-18 months); the average fracture healing time was 10.5 weeks (range: 8-14 weeks) ). No patients reported internal fixation-related soft tissue irritation. 14 patients recovered the relative motion of the knee joint of the uninvolved limb. At the last follow-up, the knee function of 16 patients showed that the average ROM was 133.75° (range: 120°~140°); The average Bostman score was 27.94 points (range: 24-30 points).

Typical case: a 42 years old female with a fracture of the inferior pole of the patella caused by a fall was treated with "net cage" technology. She was followed up regularly after operation. One year after operation, the reexamination showed that the patient achieved good clinical effect and function. The results are as follows.

## Discussion

The main treatment for inferior pole fractures of the patella is to restore the function of the quadriceps muscle and prevent the occurrence of osteoarthritis<sup>[11]</sup> through open reduction and internal fixation. Because the fractures of the inferior pole fractures are usually very small and comminuted, it is difficult to carry out effective, stable fixation,<sup>[6, 11]</sup> and long-term external fixation of the brace can cause knee dysfunction. In order to better fix the fracture of the inferior pole of the patella, many fixation methods have been applied. Lazaro et al. reported<sup>[12]</sup>: circular ligation and suture fix the fracture of the inferior pole of the patella, the wire band cannot effectively close the proximal articular surface of the patella, and the fracture fragments can easily enter the joint cavity. Zhu et al<sup>[9]</sup>. reported that the microplate and tension band wiring in the treatment of inferior pole fractures of the patella have achieved certain clinical effects. Although the plate fixation of fractures provides a new idea for our treatment<sup>[9, 13, 14]</sup>, because the patella is a sesamoid, its surface is not flat, and there is no guarantee that the plate can be placed in a suitable position; in addition, the inferior pole of the patella and the gap between the patellar ligaments is very small, and placing a steel plate may increase the damage to the tissue structure. Assaf et al<sup>[15]</sup>. reported that anchor suture fixation is to suture the inferior pole fracture and the patellar ligament together to reconstruct the knee extension function. However, this fixation may have insufficient strength, and the postoperative brace fixation is still insufficient for early functional exercise. Basket plate fixation<sup>[13]</sup> and x-change acetabular revision mesh<sup>[16]</sup> may be promising alternatives, but there may be complex operations and greater trauma.

Partial resection of the patella is also used to treat fractures of the inferior pole of the patella, especially for comminuted fractures of the inferior pole of the patella<sup>[17-19]</sup>. However, a large number of studies have shown that partial patella resection will cause many unsatisfactory results. Kaufer<sup>[20]</sup> proved that the knee extension mechanism function of the knee joint after partial patella resection is reduced by 30%; resection of the inferior pole of the patella changes the length of the patellar tendon and makes the patella oriented moving downward, the end of the patellar ligament moves backward, changing the local mechanical distribution, which may interfere with the physiological function of the patellofemoral joint and cause a series of long-term complications<sup>[4, 21]</sup>. Therefore, the patella should be preserved as much as possible.

Tension band wiring fixation is considered to be the gold standard for optimal knee function recovery in patients with patella fractures<sup>[22]</sup>. The quadriceps contraction of the knee joint can tear apart the fragments at the fracture site of the patella. The tension band wiring fixation converts this tension into compression so that the bone can withstand high tension loads and promote bone healing<sup>[2]</sup>. Studies have described the internal fixation of displaced inferior patella pole fractures with anterior tension band wiring

through cannulated screws and achieved good clinical results<sup>[6]</sup>. However, this fixation method still requires a large fracture fragment to support the wire with screws, and it cannot be effectively fixed for small, comminuted inferior pole fixation. The traditional tension band wiring fixation was abnormal, and some complications were reported, such as bone needle withdrawal, steel wire fracture, internal fixation cutting. In order to solve these problems, we proposed an innovative fixation method: "net cage" technique and achieved good clinical results in many years of clinical practice. We believe that this technique can provide a way for the clinical treatment of inferior patella fractures.

Our fixation technology is not just two sets of tension bands. First of all, a fracture of the inferior pole of the patella can be regarded as a special avulsion fracture. It does not participate in the articular cartilage surface of the patella. We only need to reconstruct the continuity of the patella and the patellar ligament to restore the knee extension mechanism of the knee joint. The concept is similar to anchor suture fixation<sup>[15]</sup>. The "net cage" structure composed of bone pins and steel cables can effectively fix the fractured mass and patellar ligament of the inferior pole to the broken end of the patella, providing strong fixation for the fracture of the inferior pole (see Fig. 1e). Secondly, during the operation, we can directly touch the articular surface with our hands during the process of inserting the 3 bone spicules from bottom to top. This not only reduces the number of intraoperative fluoroscopy but also ensures more precise insertion of the bone spicules. Drive 3 bone spicules parallel to the articular surface into the subchondral bone area. This area has a stronger bone condition and reduces the risk of disengagement and failure of the tension band due to the withdrawal of the spicules (due to the injury mechanism, fractures of the inferior pole of the patella are often compressed and comminuted in layers, and the bone mass is poor, which potentially reduces the firmness of the fixation). Meanwhile, the three bone spicules are held parallel under the distal fracture fragments, which is similar to the raft nail effect<sup>[23]</sup> (similar to the tibial plateau fracture plate) to better support the inferior pole fracture fragments. It forms a cross mesh structure with the two tension band steel cables on the upper surface of the fracture fragments. The three-dimensional wrapping is similar to the "net cage" structure, which firmly hoops the inferior pole fracture fragments on the patella body, to restore the continuity of patellar ligament and reconstruction of knee extension device. Finally, we choose two sets of tension bands for fixation for many reasons: 1. The "net cage" structure composed of the two sets of tension band pins and steel cables is smaller, which can prevent fracture fragments from leaking from the "net cage" structure; 2. One set of tension band fixation is prone to cutting between internal fixation and fracture fragments. When the two sets of tension bands are fixed, the contact area between the lower pole fracture block and the internal fixation increases, and the pressure on the contact surface will decrease accordingly, reducing the occurrence of cutting. 3. Even if one set of tension bands is withdrawn or loosened, the other set of tension bands will still play a role to avoid complete failure of internal fixation. This has been confirmed in 34-C patella fractures.

In our study, the fractures of all patients were healed without internal fixation loosening, rupture, and other complications, and during the operation of the knee joint, we found that the "net cage" technology to fix the inferior pole of the patella fracture was very firm, and there was no need routine to wear a brace after the operation. The patient can actively or passively move the knee joint early so that the patient can obtain better knee joint function. In our study, 14 patients recovered the relative motion of the knee joint of the

uninvolved limb. At the last follow-up, the knee function of 16 patients showed that the average ROM was 133.75°, which confirmed that “net cage” technology is beneficial to patients Recovery of knee joint function.

Our study also has limitations. First, this is a retrospective study. The relatively small sample size and the lack of a control group may cause bias in the results. Second, although good results have been achieved in clinical applications, there is a lack of biomechanical research on this technology. Third, this technique also needs to wear a brace after the operation in elderly patients with severe fractures and porosity, which may increase the occurrence of joint stiffness to a certain extent. In this regard, we look forward to conducting a large-sample, multi-center randomized controlled study to confirm the results of the study, and we are also conducting further studies on the biomechanics of the “net cage” technology.

## **Conclusions**

“Net cage” technology for the treatment of fractures of the inferior pole of the patella is a safe and effective fixation method. It has the advantages of simple operation, reliable clinical efficacy, reduced fluoroscopy, promotion of early functional exercise of patients, and better knee joint function.

## **Declarations**

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### **Ethics approval**

This study was performed in line with the principles of the Declaration of Helsinki. This study was approved by the ethics committee of Hong Hui Hospital, Xi'an Jiaotong University (Xi'an, Shaanxi, China; 20170222). All patients provided informed consent prior to participation in the study.

### **Consent to Participate**

All patients and their families signed informed consent before operation. This study was approved by the ethics committee of Xi'an Hong Hui Hospital.

### **Consent to publication**

All authors agreed to publish.

### **Authors' contributions**

Zhong Li and Hongfei Qi were responsible for the study design, the definition of

intellectual content, and for literature research. Yao Lu, Hanzhong Xue and Cheng Ren analyzed and interpreted data. Ming Li drafted the manuscript. Kun Zhang, Yanling Yang, Teng Ma and Zhong Li revised the manuscript. All authors read and approved the final manuscript.

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## Competing interests

The authors declare that they have no competing interests.

## Availability of data and materials

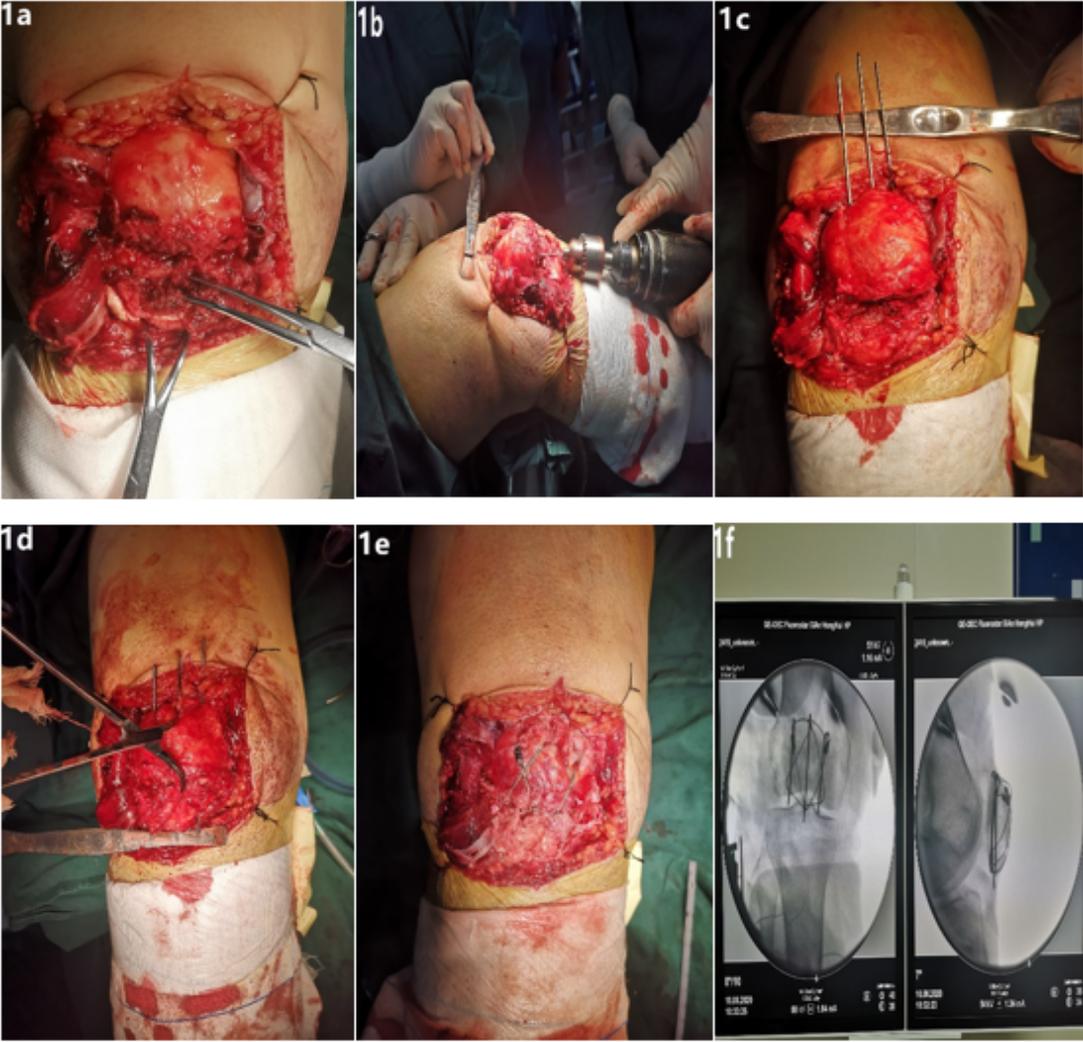
The data and materials of this study can be obtained from the corresponding author. We will actively provide relevant information upon reasonable request.

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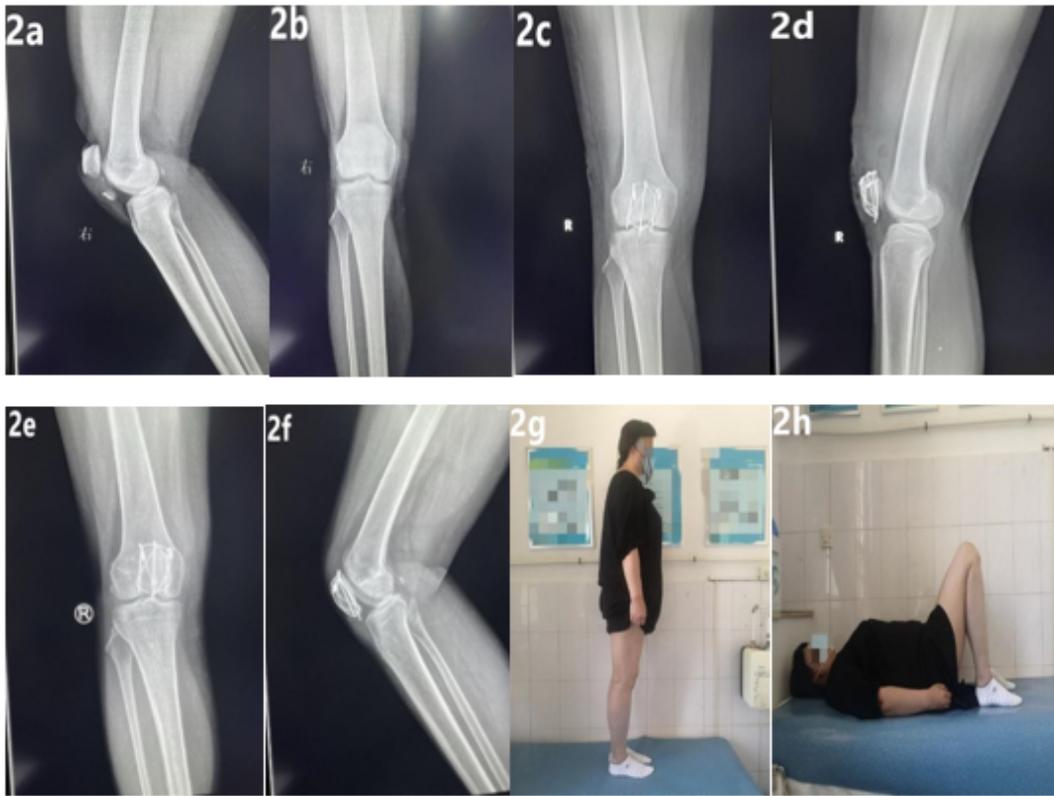
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# Figures



**Figure 1**

Intraoperative process of "net cage" technique in the treatment of inferior patellar fracture



**Figure 2**

A 42 years old female patient with distal patellar fracture. Knee radiographs(a-b ) preoperation,(c-d)day 2 after operation,(e-f) one year after operation g-h functional appearance of the knee joint 1 year after operation.

## Supplementary Files

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