RESEARCH ARTICLE

Treating Inferior Pole Fracture of Patella with Hand Plating System: First Clinical Results

Xiang-Yu Ma, MD, PhD[1], Dong Cui, MD, PhD[2], Bing Liu, MD, PhD[1], Zheng Wang, MD, PhD[1], Hai-Long Yu, MD, PhD[1], Hong Yuan, MD[1], Liang-Bi Xiang, MD, PhD[1], Da-Peng Zhou, MD, PhD[1]

[1]*Department of Orthopaedics of General Hospital of Northern Theater Command, Shenyang and* [2]*Department of Cardiology of No.967 Hospital of PLA Joint Logistics Support Force, Dalian, Liaoning Province, China*

Objective: Inferior pole fractures of patella are notorious fractures where it is difficult to obtain rigid internal fixation by conventional methods. The objective of the study was to introduce the Hand Plating System (HPS), which was a novel surgical technique for inferior pole fractures of patella, and to report the radiological and clinical outcomes following the application of the surgical technique.

Methods: The study was designed as a retrospective cohort study. Between July 2017 and December 2018, 30 patients who were diagnosed with inferior pole fracture of the patella without additional orthopaedic injuries were enrolled in this case series. After X-ray and 3D-CT examinations, all patients underwent open reduction and internal fixation by HPS with or without supplementary cannulated screw and lag screw stabilization. The bony union time, final range of motion (ROM), Bostman score, visual analog scale (VAS), and complications were measured as the clinical outcomes under a minimum of 12 months of follow-up.

Results: All of the operations went well with the mean operative time of 76.2 $\pm$ 15.3 min. Bony union achieved in all the cases at an average of 9.5 $\pm$ 1.4 weeks after surgery. There was no loss of reduction, fixative failure, or surgical implant removal during follow-up. The average range of motion 1 year postoperatively was 0°–123.3°. The mean Bostman Score at the last follow-up was 26.8 $\pm$ 2.1 with the satisfactory rate of 100%. The pain feeling during walking as measured by VAS averaged at 0.9 $\pm$ 1.3. No complications developed except for one case of poor incision healing, which healed eventually after surgical debridement.

Conclusions: HPS was demonstrated as a secure fixation and as a kind of tension band for inferior pole fractures of the patella. Satisfactory recovery of knee function and low complication rate, including no need for hardware removal, could be expected.

Key words: HPS; Inferior pole; Internal fixation; Patella fracture; Tension band

Introduction

Patella fractures are common, encompassing approximately 1% of skeletal fractures.[1] Among them, inferior pole of patella fractures account for 9%–22% of all the patella fractures undergoing surgical treatment.[2] Inferior pole fractures of patella refer to the fractures occurring at the distal part of the patella, which is the starting part of the patellar tendon and the extensor and flexor stress is concentrated. As it directly interrupts the knee extension structure and is seldom stable, the inferior pole fracture of patella is a surgical challenge, especially for some small and comminuted fragments with obvious displacement.

In the past few years, various techniques have been described to solve the problem in the literatures.[3–5] A study once proposed the application of vertical wire and screw in combination with circular ligation and suture.[6] But the wire banding was not able to close the articular surface of inferior

Address for correspondence Liang-Bi Xiang, MD, PhD, Department of Orthopaedics of General Hospital of Northern Theater Command, Shenyang, Liaoning Province, China 116011 Tel./Fax: +86-024-28851277; Email: xiangliangbi1963@sina.com. Da-Peng Zhou, MD, PhD, Department of Orthopaedics of General Hospital of Northern Theater Command, Shenyang, Liaoning Province, China 116011; Email: me3210@163.com
Xiang-Yu Ma, Dong Cui. These authors contribute equally to this work.
Received 18 March 2022; accepted 10 August 2022

pole effectively, which facilitated debris entering into the articular cavity easily. Meanwhile, this kind of wire fixation affected the supply of blood vessels around patella. So many potential adverse effects might occur in the long run including debris retention in the knee joint and delayed bony union or nonunion due to disruption of blood supply.[7] Some Chinese scholars suggested the use of claw-like shape memory alloy due to the advantages of continuous recovery stress. However, the technique was less helpful for comminuted inferior pole fractures. Additionally, the mechanical strength of the memory alloy implant in the cyclic knee flexion and extension was worrying.[8] Due to the difficulty of fixation to the small inferior pole fragments, some scholars[9] considered that the severely comminuted fragments of the lower patella could be partially resected. However, the connection of tendon to bone was weak and took a longer time to heal compared to a bone-to-bone interface, which often required the patients to be in prolonged immobilization.[3] In addition, the partial resection might lower the height of patella, which made the position of the patellar ligament imbalanced with the patella, leading to uneven force on the articular surface and accompanying knee joint degeneration.[10]

There has been a recent trend towards the fracture treatment using plate fixation such as the commonly used mesh-locking plate[11] and angular stable plate.[12] This method allowed for more rigid stabilization and earlier mobilization with potential for improved functional outcomes and a decrease in symptomatic hardware, particularly in the case of comminuted fracture patterns.[13] However, under the continuous stress from the patellar tendon, the common patellar plate design is hard to achieve a fixation rigid enough to control these small-sized fragments.[14] To improve the reduction construct, some new designs were introduced in the literature for osteosynthesis of the inferior pole of the patella, such as a hook at the distal end of the plate with compression screws[15,16] or a rim plate beneath the patellar tendon.[3] However, these current techniques remained less helpful for the severely comminuted inferior pole fractures, with certain complications and historically poor functional outcomes. For example, some patients still complained of discomfort or anterior knee pain, especially when kneeling with these implants, due to the thickness and stiffness of the plate implants in the inferior pole of patella.[14]

To prevent the complications and improve the functional outcomes, we proposed the application of OSTEOMED® Hand Plating System (HPS), which was a rigid fixation system consisting of plates and screws made of titanium alloy. The HPS plate were provided in a variety of shapes and sizes including "T shape" and "Y shape," and offered surgeons compression and locking hole designs. During the surgical treatment for inferior pole fracture of patella, the precontoured HPS plate was positioned into the patellar ligament after fragment reposition. The multiple screws could be placed from the distal multidirectional holes within 12° of HPS into the subchondral bone of the proximal patella, functioning as a compression and blocking construct. Sometimes the HPS fixation was combined with the assistance of cannulated screw and/or lag screw for more rigid compression, in compliance with Pauwel's principle.[15] Up to now, there have been no reports about the clinical application of this technique. We have adopted the HPS plate fixation in management of patella inferior fractures for 3 years, which might be an effective and safe option for the treatment of these challenging fracture patterns. The purpose of this study was (i) to assess the feasibility of the HPS technique in treating inferior pole fractures of the patella; (ii) to evaluate the safety of the surgery with HPS fixation; and (iii) to evaluate the radiological and clinical outcomes in patients using the technique.

Materials and Methods

Inclusion and Exclusion Criteria

This study was conducted as a retrospective cohort study, which was approved by the local ethics board of our institution (Y (2022) 038). The inclusion criteria were as follows: (1) patients diagnosed with AO classification of 34-A1/C1.3 patella fractures; (2) patients treated operatively and fixed with the HPS technique; (3) postoperative follow-up not less than 1 year with full postoperative radiological and clinical outcomes. The exclusion criteria were: (1) pathological or non-traumatic fracture; (2) open fractures; (3) patients with prior limited knee function or with additional orthopaedic injuries.

Patient Demographics

Between July 2017 and December 2018, 35 patients with inferior pole fractures of the patella received HPS with or without combination of cannulated screw and/or compression screw. Among the patients, three patients who were associated with ipsilateral distal femur fracture and two patients lost to follow-up were excluded according to the exclusion criteria. A total of 30 patients (17 males and 13 females) were enrolled in the retrospective case series. The mean age of the enrolled patients was 60.6 ± 10.5 years (range 40–86 years). The injury mechanism included slip on knees in 21 cases, fall injury in 6 cases, and traffic accident in 3 cases.

All patients were treated operatively on average of 3.2 days (range 0–7 days) after suffering the fracture. After hospitalization, initial X-ray and 3D-computed tomography (CT) scan were taken preoperatively to evaluate the fractures. The taken radiographs were calibrated to allow for a valid measurement of the length of displacement. All the enrolled patella fractures were classified according to the AO/OTA fracture classification[17] and listed in Table 1. The average number of fragments was 3.7 ± 1.3 (range 2–6), and the mean length of displacement between the main fragments was 7.1 ± 4.5 mm (range 3–23 mm) according to the measurement of preoperative images (Fig. 1).

Surgical Technique

The distal end of the "T shape" and "Y shape" HPS plate (OsteoMed, Addison, TX, USA) with the three locking holes would function as a compression and blocking construct

Table 1 Patient demographics and surgical details

Case	Gender [M/F]	Age [years]	Classification (AO)	Injury mechanism	No. of fragments	Displacement between main fragments (mm)	Implant	Shape of HPS palte	Operative time (min)
1	M	40	C1.3	Slip on knees	4	5	HPS (10 holes, 5 screws), cannulated screw (1), lag screw (2)	T	75
2	M	51	C1.3	Slip on knees	2	3	HPS (10 holes, 5 screws)	T	108
3	M	63	C1.3	Slip on knees	3	23	HPS (10 holes, 6 screws), lag screw (4)	T	72
4	F	73	C1.3	Slip on knees	5	12	HPS (10 holes, 8 screws), lag screw (3)	T	110
5	F	61	C1.3	Slip on knees	2	7	HPS (10 holes, 6 screws)	T	65
6	F	59	C1.3	Slip on knees	6	3	HPS (10 holes, 6 screws), cannulated screw (1)	T	75
7	M	58	A1	Slip on knees	5	3	HPS (10 holes, 6 screws)	T	60
8	M	48	C1.3	Fall injury	6	6	HPS (11 holes, 6 screws)	T	105
9	F	56	C1.3	Slip on knees	5	8	HPS (11 holes, 5 screws), lag screw (6)	T	82
10	F	68	C1.3	Slip on knees	2	3	HPS (10 holes, 6 screws)	T	60
11	M	86	C1.3	Slip on knees	2	18	HPS (10 holes, 6 screws), cannulated screw (2)	Y	55
12	F	64	C1.3	Slip on knees	3	6	HPS (9 holes, 6 screws), lag screw (3)	T	78
13	M	71	C1.3	Traffic accident	5	8	HPS (10 holes, 4 holes, 7 screws), lag screw (4)	Y	95
14	F	79	A1	Slip on knees	2	14	HPS (9 holes, 5 screws)	T	62
15	M	52	C1.3	Fall injury	3	3	HPS (11 holes, 4 screws), cannulated screw (2)	T	70
16	M	42	C1.3	Fall injury	4	6	HPS (10 holes, 6 screws), lag screw (2)	Y	79
17	F	70	C1.3	Slip on knees	5	4	HPS (10 holes, 7 screws), lag screw (3)	T	82
18	M	56	C1.3	Slip on knees	3	7	HPS (11 holes, 5 screws), cannulated screw (1)	Y	72
19	F	63	A1	Slip on knees	3	6	HPS (10 holes, 7 screws)	T	61
20	M	69	C1.3	Fall injury	5	10	HPS (11 holes, 6 screws), cannulated screw (1), lag screw (3)	T	90
21	F	57	C1.3	Traffic accident	4	9	HPS (10 holes, 6 screws), lag screw (2)	T	68
22	M	64	C1.3	Fall injury	4	6	HPS (11 holes, 7 screws)	Y	64
23	M	52	C1.3	Slip on knees	2	4	HPS (10 holes, 5 screws)	T	58
24	F	65	C1.3	Slip on knees	6	6	HPS (10 holes, 6 screws), cannulated screw (1), lag screw (1)	Y	84
25	M	55	A1	Slip on knees	3	4	HPS (10 holes, 6 screws)	T	60
26	M	44	C1.3	Traffic accident	4	3	HPS (10 holes, 7 screws), lag screw (3)	T	78
27	F	70	C1.3	Slip on knees	3	5	HPS (10 holes, 7 screws)	T	66
28	M	51	C1.3	Slip on knees	4	11	HPS (10 holes, 7 screws), cannulated screw (2)	T	88
29	F	68	C1.3	Fall injury	3	7	HPS (11 holes, 6 screws), cannulated screw (1), lag screw (2)	Y	100
30	M	62	A1	Slip on knees	2	9	HPS (11 holes, 8 screws)	T	64
Mean ± SD	—	60.6 ± 10.5	—	—	3.7 ± 1.3	7.1 ± 4.5	—	—	76.2 ± 15.3

(Fig. 2). T type fixation was optimal for most inferior pole fractures. Y type was suitable for those with fragments near the articular facet. All surgeries were performed by three surgeons in a single trauma team, following the steps below.

Anesthesia and position: Patients were placed in supine position under spinal or general anesthesia. The injured lower limb was draped in a manner which allowed free movement during the operation. The knee joint was positioned in extension after the inflation of a pneumatic tourniquet. Approach and exposure: A longitudinal midline incision with the length of approximately 8 cm was made on the anterior aspect of the knee. Subsequently, the

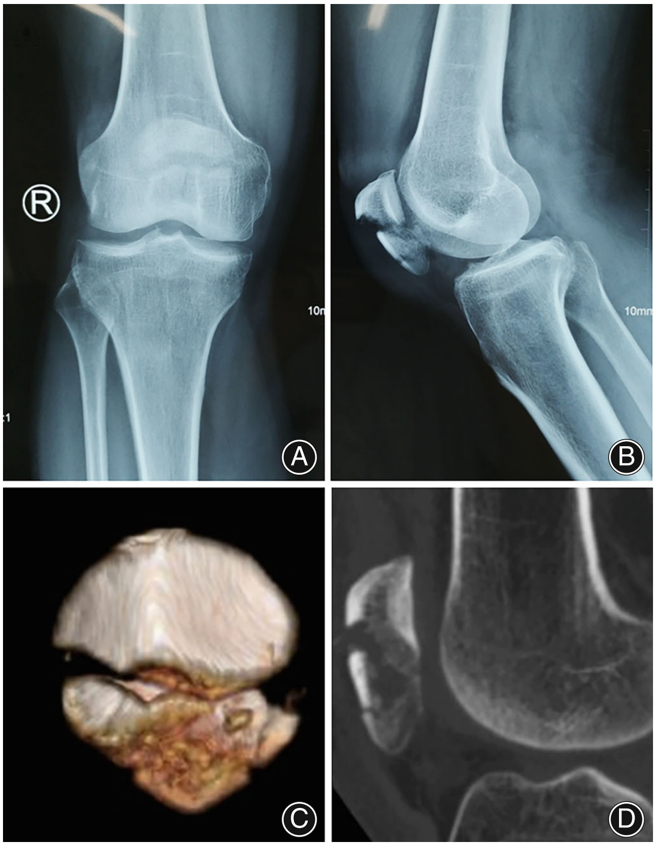

Fig. 1 Preoperative imaging examinations of Patient 1 showing a multifragmented fracture of inferior patella pole with AO classification of C1.3; (A) Anterioposterior and (B) lateral images of X-ray examination; (C) 3D reconstruction of the patella; (D) Tomographic image in sagittal plane showing the details of distal fragments

subcutaneous medial and lateral flaps were elevated to completely expose the lower half of the patella and the upper half of patellar tendon with a clear view of the lesion. The patella fragments were reduced anatomically using reduction forceps and provisionally fixed with K-wires. If the fracture pattern was amenable to interfragmentary fixation, the comminuted fracture was first stabilized using lag screws (2.0/2.4 mm, Osteomed).

Fixation of the prosthesis: The HPS plate was accurately bent to match the shape and contour of the patella. After the patellar tendon was partially split, the plate was placed over the patella with the distal end beneath the patellar tendon and along the inferior pole coronally (Fig. 3A). For the comminuted fracture of the inferior pole of the patella, the plate could be directly compressed on the inferior pole without patellar tendon resection. After the plate was compressed onto the patella with the appropriate implantation of cortical screws, the locking screws from the distal holes of the HPS plate should be fixed into the subchondral bone of the proximal fragment to hold the proximal patella and to create a pre-load to the inferior fragments. If the compression provided by the HPS plate and screws was not enough, additional cannulated screws (3.0/4.0 mm, Osteomed) were inserted perpendicularly to the fracture line for static compression, in order to facilitate bone healing. If the comminuted distal fragments could not be constructed as a whole by the HPS plate, additional lag screws (2.0/2.4 mm) were utilized to hold the small fragments. The number of screws was not only determined by the AO classification or the number of fragments, but also was depended on the site of fracture line and the coverage area of the plate (Table 1). All the

Fig. 2 HPS plate (“Y-shape” [left], precontoured “T-shape” [right]) for the fixation of inferior patella fractures

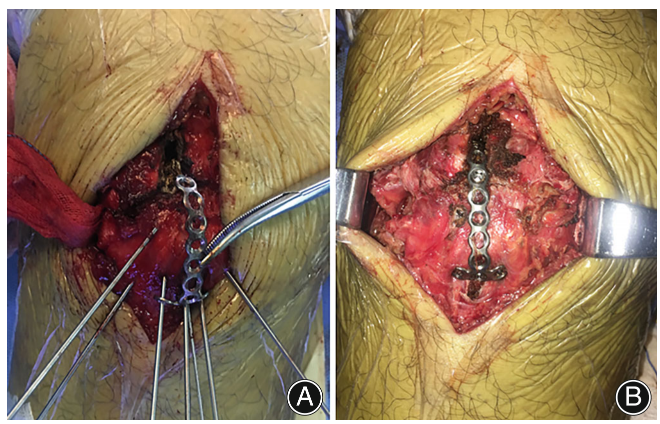

Fig. 3 Intraoperative photographs of patella fracture reduction obtained using the “T-shape” plate of HPS; (A) Placement of pre-contoured plate after reduction and K-wire provisional fixation; (B) The completed fixation of plate and screws

Table 2 Bostman Score System

Variable	Points (maximal 30)
Range of motion	
Full extension and range of motion >120° or within 10° of normal side	6
Full extension, motion 90°–120°	3
Pain	
None or minimal on exertion	6
Moderate on exertion	3
In daily activities	0
Work	
Original job	4
Different job	2
Cannot work	0
Atrophy, difference of circumference of thighs 10 cm proximal to the patella (mm)	
<12	4
12–25	2
>25	0
Ambulation assistance	
None	4
Walking stick (part time)	2
Walking stick (all the time)	0
Effusion	
None	2
Reported to be present	1
Present	0
Giving way	
No	2
Sometimes	1
In daily life	0
Stairclimbing	
Normal	2
Disturbing	1
Disabling	0

inferior pole fragments should be nestled by the distal end of HPS or the separated screws into their original location and be blocked from distal displacement. After the internal fixation (Fig. 3B), the articular surface was palpated through the retinacular rent for confirmation of anatomic reduction and no screw penetration into the joint. Reconstruction: The retinaculum was then repaired and the stab incisions of the patellar tendon were tightly sutured. Finally, the surgical incision was closed in layers over a negative suction drain.

Postoperative Care and Rehabilitation

The knee bandaged with soft dressings was placed in a hinged knee brace locked in full extension. Radiographs were obtained to verify implant position and fracture reposition 2 days post operation. Subsequently, muscle strengthening exercises and continuous passive motion were encouraged, depending on the complexity of the fracture. In general, 0° to 90° of flexion in brace was allowed for the first 2 weeks postoperatively and allowed for weight bearing thereafter. Afterwards, progressive unrestricted ROM exercises were started under the supervision of a physical therapist.

Outcome Measures

Operative Time

The total operative time was calculated from the time point of incision to the finish of skin closure for a general assessment of the difficulty and complexity of the surgical procedure.

Bony Union Time

During the follow-up, we documented the bony union time of fracture on X-ray examination postoperatively. The bony union was defined as the loss of the fracture line and the presence of bony trabecular continuity.[18] A prolonged bony union time often indicated an unstable fixation or impairment to the blood supply.

Functional Evaluation

The range of motion (ROM) of knee joint at each follow-up was measured with a goniometer to evaluate the amount of movement of knee joint. The commonly used clinical knee score-Bostman Score System was applied to evaluate the knee joint function (Table 2).[19] In accordance with the system, the functional results were divided into three categories: Excellent was defined as 30–28; Good was defined as 27–20; Unsatisfactory was defined as less than 20. Satisfactory rate was calculated according to the cases with excellent and good functional results divided by all the cases.

Visual Analog Scale

The patients were asked to subjectively rate their pain during walking using the visual analog scale (VAS), which was a validated, subjective measurement for acute and chronic pain. The VAS was used to evaluate the postoperative knee joint pain after surgery.

Complications

The incidence of complications influenced the safety and feasibility of the surgery. The potential complications including infection, internal fixation failure or breakage, implant irritation, knee joint pain, and knee stiffness were recorded.

Results

Follow-Up

The mean follow-up duration was 13.8 ± 2.1 months (range 12–20 months) after primary surgery (Table 3). All the patients were followed up in the routine outpatient clinics, first at 1 month, then 3-monthly until the 12th month. During each follow-up, a physical examination was performed, and the ROM of the involved knee was measured. A routine X-ray was taken to assess the bone healing and the position of the implants.

General Results

Among all the patients, the inferior pole fractures were fixed using the HPS (9–11 holes, stabilized with 4–8 screws) with assistant cannulated screw stabilization in 9 patients and lag

Table 3 Clinical results post operation

Case	Follow-up duration (month)	Bony union	Union time (week)	Final ROM	Bostman Score	VAS	Complication
1	13	Y	10	0°–140°	29	1	N
2	20	Y	10	0°–120°	26	0	N
3	13	Y	12	0°–120°	30	0	N
4	14	Y	12	0°–100°	23	3	N
5	15	Y	8	0°–130°	30	0	N
6	14	Y	10	0°–130°	29	0	N
7	14	Y	8	0°–130°	28	0	N
8	13	Y	10	0°–110°	26	2	N
9	12	Y	10	0°–130°	28	0	N
10	12	Y	8	0°–130°	27	0	N
11	12	Y	10	0°–110°	23	4	Poor healing of incision
12	12	Y	8	0°–120°	27	0	N
13	13	Y	10	0°–120°	25	2	N
14	12	Y	10	0°–130°	26	0	N
15	12	Y	8	0°–140°	29	0	N
16	14	Y	10	0°–110°	26	0	N
17	15	Y	10	0°–120°	26	1	N
18	18	Y	8	0°–130°	29	0	N
19	13	Y	8	0°–130°	28	0	N
20	12	Y	12	0°–110°	24	4	N
21	16	Y	10	0°–130°	27	0	N
22	19	Y	8	0°–130°	26	1	N
23	12	Y	8	0°–130°	28	0	N
24	12	Y	12	0°–120°	24	3	N
25	14	Y	8	0°–120°	25	1	N
26	15	Y	10	0°–110°	26	2	N
27	13	Y	8	0°–130°	29	0	N
28	16	Y	10	0°–130°	25	1	N
29	13	Y	12	0°–110°	24	3	N
30	12	Y	8	0°–130°	30	0	N
Mean ± SD	13.8 ± 2.1	—	9.5 ± 1.4	0°–123.3°	26.8 ± 2.1	0.9 ± 1.3	—

screw stabilization in 13 patients. The details of the fixation implants were exhibited in Table 1. The operative time was on average 76.2 ± 15.3 minutes (range 55–110 minutes, Table 1). The anterioposterior and lateral images of X-ray examination 2 days post operation showed excellent fracture reductions and implant positions with different fracture and fixation types (Fig. 4).

Radiological Improvement

During the follow-up period, no loss of reduction or fixative failure occurred. Fracture healing, as documented on X-rays, was achieved on average of 9.5 ± 1.4 weeks after surgery (range 8–12 weeks, Table 3). At the 12-month follow-up, the X-ray examination showed complete healing of fractures and good position of implants (Fig. 5 A and B for Patient 1, E and F for Patient 5, G and H for Patient 25).

Functional Evaluation

At the 12-month follow-up, the average range of motion was 0° to 123.3° (range 0° to 100°–140°, Table 3). Seventeen patients recovered full range of motion relative to the contralateral limb, accounting for 56.7% of all the patients (Fig. 5 C and D, Patient 1). The mean Bostman Score at the last follow-up was 26.8 ± 2.1 (range 23–30, Table 3), including excellent for 12 cases and satisfactory for 18 cases. The satisfactory rate was 100%.

Clinical Improvement

All the patients could walk independently with weight-bearing within 12 weeks. As measured by VAS, pain feeling during walking averaged at 0.9 ± 1.3 (range 0–4, Table 3).

Complications

During the follow-up period, there was one poor incision healing, sustained by an 86-year-old male with diabetes mellitus at 2 weeks post operation. Surgical debridement was performed with the implant retained, as the bacterial culture result showed negative result. Bony union achieved at 10 weeks after the primary operation without further recurrence. No surgical implant removal was undertaken among all the patients. At the final follow-up, no patients complained of implant irritation or knee joint pain.

Discussion

Our Current Findings

In our series, we found that the HPS possibly combined with cannulated/lag screw adequately addressed both

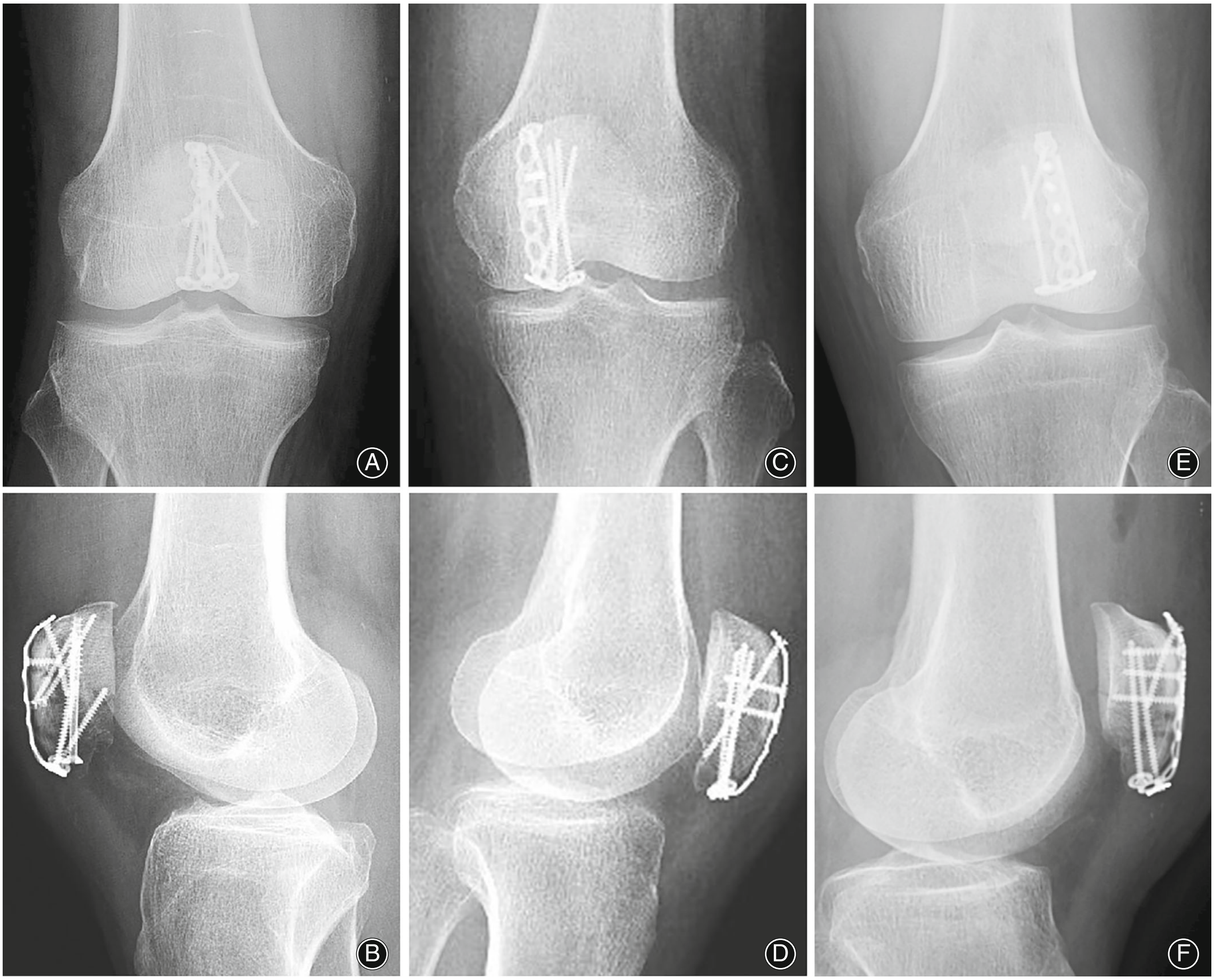

Fig. 4 Postoperative radiographs of HPS fixation 2 days post operation. (A) Anterioposterior and (B) lateral images of Patient 1 with AO classification of C1.3 with cannulated screw and lag screw fixation; (C) Anterioposterior and (D) lateral images of Patient 5 with AO classification of C1.3 without supplemental screw fixation; (E) Anterioposterior and (F) lateral images of Patient 25 with AO classification of A1 without supplemental screw fixation.

simple and comminuted fractures regardless of the fragment displacement involving the inferior pole. All the fractures achieved bony union within 12 weeks. Only one case of poor incision healing occurred, which was treated by debridement without implant removal. The method allowed for early postoperative rehabilitation with the protection of brace. The final knee joint function was satisfactory as supported by the optimal ROM, Bostman Score, and VAS evaluation. Up to the last follow-up, there had been no implant failure in any patient in this series. As the rim plate did not cause laceration or irritation of the patellar tendon, no patient complained about the prominence of the implant.

Current Status

The fracture of the inferior patellar pole is characterized by coronal stratification, thin section, and comminuted fracture,[5] which cause a continuous interruption of the knee extension device. The optimal surgical technique for the fixation of inferior pole fractures of the patella remains controversial, although some new techniques have been recently proposed.[3,4,20] The previously used partial patellectomy and repair of the patellar tendon was demonstrated to change the length of the patellar tendon, resulting in a series of long-term complications.[21] Nowadays, the principle of treatment is to reconstruct the knee extensor mechanisms, as well as anatomical reduction of articular surface.[22] Generally,

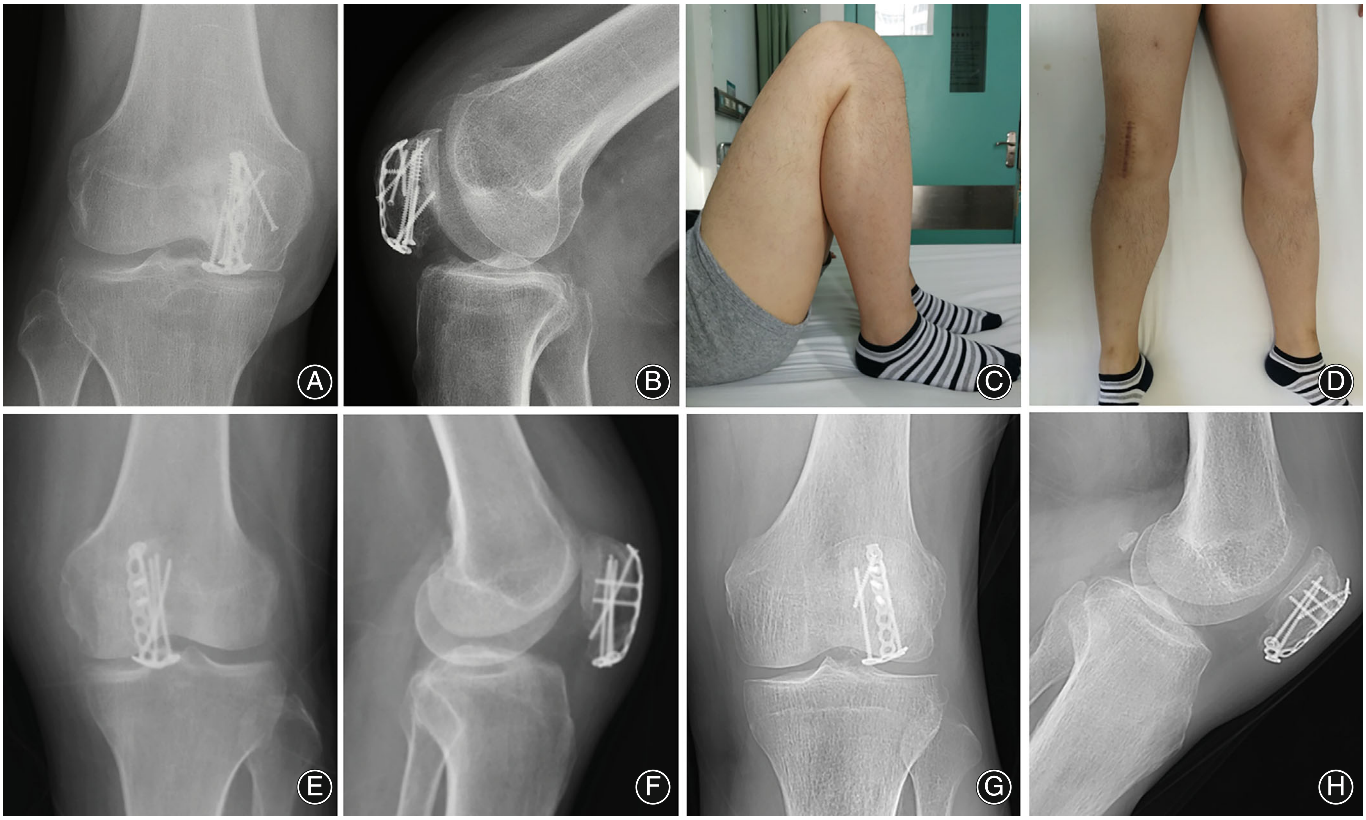

Fig. 5 The follow-up at 12 months post operation. (A) Anteriopposterior and (B) lateral X-ray images showing good bone healing and implant position of Patient 1. Maximum of (C) extension and flexion (D) of knee joint showing fully recovered range of motion (0–140°) of Patient 1. (E) Anteriopposterior and (F) lateral X-ray images showing good bone healing and implant position of Patient 5. (G) Anteriopposterior and (H) lateral X-ray images showing good bone healing and implant position of Patient 25.

contemporary methods for operative treatment of inferior pole fractures of the patella include some form of a tension band construct, possibly with rigid compression at the site of the fracture.[13] The tension band constructs employ a variety of implants, containing Kirschner wires, cannulated screws, cables, plate, and suture.[23] Currently, osteosynthesis is based on more recent separate vertical screw with plate technique and their modifications.[24]

Advantages, Pitfalls, Practicality, and Experience of the Technique

Recent studies have described the use of plates for patella fractures with good results.[11,25–28] However, the conventional hook or basket plate held the inferior pole fragments through longitudinal gripping force from hooks or limited screws within the holes, which could not generate compressive forces across fracture fragments.[3] The advantages of the technique was that engaging and tightening each locking screw through the holes of the distal end of the HPS plate allowed for compression of the inferior fragment towards the proximal patella, and blocked them from distal displacement. Secondly, the multidirectional holes within 12° in the distal end provided more potential points and directions of fixation, beneficial in binding the distal comminuted fragments together. Thirdly, the HPS plate acted as a kind of tension band for continuous compression of the major fragments in this fixation manner. Multiple locking screws beared the stress *via* sufficient anchorage, which would largely avoid cutting through the bone. There was a pitfall which should be avoided. If the inferior sleeve fragments were too comminuted to be directly reduced, the distal end of the HPS plate should be compressed on the distal pole to provide an indirect reduction of the inferior fragments that enabled a firm bone-to-bone union while minimally harming the patellar tendon or bone fragments.

In clinical practice, additional cannulated screw (3.0/4.0 mm) compression was needed in 9 patients (30% of all the enrolled patients) and lag screw (2.0/2.4 mm) fixation was performed in 13 patients (43.3%). Among them, the combined application of additional cannulated screw and lag screw was performed in 4 patients (13.3%). Morre *et al.* once provided data on patients with complex patella fractures treated with different locking plates. It was reported that 47% of the patients (17 out of 36) required additional screw osteosynthesis in that series.[29] In our experience, the lag screw was especially useful in dealing with small and communited fragments that the HPS plate was not able to reach, preventing the separation between the distal comminuted fragments. The cannulated screw provided appreciable compression between the major fragments, which made up for the relatively weak strength of HPS plate fixation.

Safety

Common surgical treatment of patella fractures was reported to be associated with persistent functional deficits and pain, possibly due to hardware impingement. In this situation, surgical implant removal had to be undertaken.[30] In our series, the HPS plate made of titanium alloy was thin enough (2.7 mm) for being contoured to entirely fit the shape of inferior pole of patella. The low-profile design of the plate, when compressed onto the bone, allowed the plate to recess into the soft tissues so that no ridge of the plate was more prominent than the surrounding soft tissue, resulting in low rates of bothersome hardware and no hardware removal. However, the mechanical strength of the thin plate was relatively weak, which seemed to be the disadvantage of this technique although no implant failure occurred.

Strengths and Limitations

This study demonstrated a novel surgical technique, HPS, as a secure fixation for inferior pole fractures of the patella with excellent clinical results. However, the study should be viewed in light of its limitations. Firstly, it was a case series without comparison group. The comparison of the present technique with other techniques would be performed in our future studies. Secondly, the follow-up in our series was relatively short term, ranging from 12 to 20 months post operation. The longer-term follow-up should be performed to reveal whether the outcomes would be maintained. Thirdly, the patients enrolled were relatively old with the mean age of 60.6 years in our study. Hence our treated patients represented a rather inactive and less sporty cohort. This might partially explain the good functional results and no occurrence of implant failure in our outcomes. Additionally, the small sample size did not allow for robust statistical analysis, which required more enrolled cases in the future for further evaluation of the technique.

Conclusions

In conclusion, we believed that the HPS technique was an alternative for treating inferior pole fracture of patella with excellent clinical results. The HPS plate could compress the inferior fragment towards the proximal patella as a tension band and blocked them from distal displacement. Supplemental cannulated screw and lag screw could be utilized as needed to achieve interfragmentary compression or additional screw osteosynthesis. The low-profile design meant it was well-tolerated and rarely required removal. However, more robust statistical analysis should be performed in the following studies.

Author's Contributions

XYM, DC, BL, and DPZ conceived and designed the experiments. XYM, DC, ZW, HLY, HY, and LBX performed the experiments. XYM and DC analyzed the data.

Conflict of Interest

The author declared that there is no conflict of interest.

Funding Information

Xiang-Yu Ma was supported by Natural Science Foundation of Liaoning Province (No. 2019-ZD-1029) and Xiang-Yu Ma was supported by the Natural Science Foundation of Liaoning Province (No. 2021-MS-038).

References

1. Heusinkveld MH, den Hamer A, Traa WA, Oomen PJ, Maffulli N. Treatment of transverse patellar fractures: a comparison between metallic and non-metallic implants. Br Med Bull. 2013;107:69–85.
2. Neumann HS, Winckler S, Strobel M. Long-term results of surgical management of patellar fractures. Unfallchirurg. 1993;96(6):305–10.
3. He QF, Pan GB, Yu ZF, Yao WX, Zhu LL, Luo CF, et al. Novel rim plating technique for treatment of the inferior pole fracture of the patella. Orthop Surg. 2021;13(2):651–8.
4. Jang JH, Cho YJ, Choi YY, Rhee SJ. Hammock plating for comminuted inferior sleeve avulsion fractures of the patella: a surgical technique and clinical results. Orthop Traumatol Surg Res. 2021;107(3):102866.
5. Fan M, Wang D, Sun K, Jiang W. Study of double button plate fixation in treatment of inferior pole of patella fracture. Injury. 2020;51:774–8.
6. Hung LK, Chan KM, Chow YN, Leung PC. Fractured patella: operative treatment using the tension band principle. Injury. 1985;16(5):343–7.
7. Lazaro LE, Wellman DS, Sauro G, Pardee NC, Berkes MB, Little MT, Nguyen JT, Helfet DL, Lorich DG. Outcomes after operative fixation of complete articular patellar fractures: assessment of functional impairment. J Bone Joint Surg Am 2013;95(14):e96 91–98, 1-8.
8. Hao W, Zhou L, Sun Y, Shi P, Liu H, Wang X. Treatment of patella fracture by claw-like shape memory alloy. Arch Orthop Trauma Surg. 2015;135(7):943–51.
9. Buezo O, Cusco X, Seijas R, Sallent A, Ares O, Alvarez-Diaz P, et al. Patellar fractures: an innovative surgical technique with Transosseous suture to avoid implant removal. Surg Innov. 2015;22(5):474–8.
10. Egol K, Howard D, Monroy A, Crespo A, Tejwani N, Davidovitch R. Patella fracture fixation with suture and wire: you reap what you sew. Iowa Orthop J. 2014;34:63–7.
11. Volgas D, Dreger TK. The use of mesh plates for difficult fractures of the patella. J Knee Surg. 2017;30(3):200–3.
12. Wurm S, Buhren V, Augat P. Treating patella fractures with a locking patella plate - first clinical results. Injury. 2018;49(Suppl 1):S51–5.
13. Siljander M, Koueiter DM, Gandhi S, Wiater BP, Wiater PJ. Outcomes following low-profile mesh plate Osteosynthesis of patella fractures. J Knee Surg. 2018;31(9):919–26.
14. Ellwein A, Lill H, DeyHazra RO, Smith T, Katthagen JC. Outcomes after locked plating of displaced patella fractures: a prospective case series. Int Orthop. 2019;43(12):2807–15.
15. Matejcic A, Smiljanic B, Bekavac-Beslin M, Ledinsky M, Puljiz Z. The basket plate in the osteosynthesis of comminuted fractures of distal pole of the patella. Injury. 2006;37(6):525–30.
16. Jang JH, Rhee SJ, Kim JW. Hook plating in patella fractures. Injury. 2019; 50(11):2084–8.
17. Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. Fracture and dislocation classification Compendium-2018. J Orthop Trauma. 2018;32(Suppl 1):S1–S170.
18. Cho JW, Kim J, Cho WT, Gujjar PH, Oh CW, Oh JK. Comminuted inferior pole fracture of patella can be successfully treated with rim-plate-augmented separate vertical wiring. Arch Orthop Trauma Surg. 2018;138(2):195–202.

19. Bostman O, Kiviluoto O, Nirhamo J. Comminuted displaced fractures of the patella. Injury. 1981;13(3):196–202.
20. Kim KS, Suh DW, Park SE, Ji JH, Han YH, Kim JH. Suture anchor fixation of comminuted inferior pole patella fracture-novel technique: suture bridge anchor fixation technique. Arch Orthop Trauma Surg. 2021;141(11):1889–97.
21. Nathan ST, Fisher BE, Roberts CS, Giannoudis PV. The management of nonunion and delayed union of patella fractures: a systematic review of the literature. Int Orthop. 2011;35(6):791–5.
22. Wright PB, Kosmopoulos V, Cote RE, Tayag TJ, Nana AD. FiberWire is superior in strength to stainless steel wire for tension band fixation of transverse patellar fractures. Injury. 2009;40(11):1200–3.
23. Bonnaig NS, Casstevens C, Archdeacon MT, Connelly C, Monaco N, Wyrick JD, et al. Fix it or discard it? A retrospective analysis of functional outcomes after surgically treated patella fractures comparing ORIF with partial patellectomy. J Orthop Trauma. 2015;29(2):80–4.
24. Wild M, Thelen S, Jungbluth P, Betsch M, Miersch D, Windolf J, et al. Fixed-angle plates in patella fractures - a pilot cadaver study. Eur J Med Res. 2011;16(1):41–6.
25. Taylor BC, Mehta S, Castaneda J, French BG, Blanchard C. Plating of patella fractures: techniques and outcomes. J Orthop Trauma. 2014;28(9):e231–5.
26. Lorich DG, Warner SJ, Schottel PC, Shaffer AD, Lazaro LE, Helfet DL. Multiplanar fixation for patella fractures using a low-profile mesh plate. J Orthop Trauma. 2015;29(12):e504–10.
27. Singer MS, Halawa AM, Adawy A. Outcome of low profile mesh plate in management of comminuted displaced fracture patella. Injury. 2017;48(6):1229–35.
28. Lorich DG, Fabricant PD, Sauro G, Lazaro LE, Thacher RR, Garner MR, et al. Superior outcomes after operative fixation of patella fractures using a novel plating technique: a prospective cohort study. J Orthop Trauma. 2017;31(5):241–7.
29. Moore TB, Sampathi BR, Zamorano DP, Tynan MC, Scolaro JA. Fixed angle plate fixation of comminuted patellar fractures. Injury. 2018;49(6):1203–7.
30. LeBrun CT, Langford JR, Sagi HC. Functional outcomes after operatively treated patella fractures. J Orthop Trauma. 2012;26(7):422–6.