A modified wire tension band technique for treatment of comminuted displaced patellar fractures

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Article

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Abstract

Purpose: Wire tension band technique, as a widely accepted strategy for the treatment of patellar fractures, is undergoing constant improvement. This study aims to assess the clinical effect of a modified wire tension band technique for treatment of comminuted displaced patellar fractures.

Methods: From January 2015 to December 2021, 97 adult patients (52 males and 45 females) with comminuted displaced patellar fractures were treated with wire tension band technique in our department. The age ranged from 18 to 68 years old with an average of 39 years old. All patients had single closed comminuted displaced patellar fractures and all were treated with open reduction internal fixation. There were 58 patients in the modified wire tension band group (The MW group) and 39 patients included in the Kirschner wire tension band group (The KW group). Operating time, intraoperative bleeding, length of hospital stay, postoperative follow-up, fracture healing time, and knee motion and function scores were recorded and compared between the two groups. The incidence of postoperative complications such as non-union of the fracture, infection, failure of the internal fixation, re-fracture, and broken of the internal fixation were recorded and evaluated. Operative time, intraoperative blood loss, post-operative clinical outcomes and radiographic results were recorded and analyzed. VAS (Preoperative and last follow-up scores in the Visual Analogue Scale) and Böstman scale were recorded and evaluated.

Results: There were no significant differences in basic information such as age, gender, BMI, mechanism of injury, history of smoking and alcohol, injured limb and follow-up time in the MW group compared to the KW group. Intraoperative time (49.91±3.88, min) in the MW group was significantly lower than intraoperative time (67.64±4.27, min) in the KW group and the difference was statistically significant (P 0.05). In the MW group (102.59±10.01, ml), intraoperative blood loss was significantly lower than in the KW group (126.41±13.86, ml), and the difference between the two groups was statistically significant(P 0.05). The intraoperative time of fluoroscopy in the MW group was (8.14±1.82, s), which was lower than the intraoperative time of fluoroscopy in the KW group (10.41±1.67, s), and the difference between the two groups was statistically significant(P 0.05). The hospital days were also significantly shorter in the MW group (6.07±1.23, d) than in the KW group (6.79±1.42, d). The difference was statistically significant(P 0.05). There was no significant difference between the two groups in terms of fracture healing time, mobility, VAS score and Böstman score after surgery. There were no complications such as infection or non-healing fractures. However, there were 2 cases of wire fracture complications in both the MW and KW groups when the internal fixation was removed.

Conclusion: The modified wire tension band technique for fixation of patellar fractures is an effective new technique for the safe and reliable management of patellar fractures and offers an alternative strategy for the treatment of patellar fractures.

Introduction

The patellar is located in front of the knee joint, anteriorly within the quadriceps tendon, posteriorly on the articular surface and distally attached to the patellar ligament, and is the largest sesamoid bone in the body. Patellar fractures account for approximately 1% of all fracture injuries in the body[1]. The choice of treatment for patellar fractures varies depending on the displacement of the fracture, the staging and patient factors. However, for clearly comminuted, displaced patellar fractures, such as those with disruption of the extensor mechanism or >2 to 3 mm sub-step and >1 to 4 mm displacement, open reduction internal fixation is recommended[2].

In the 1950s, the Kirschner tension band technique was first used in the treatment of patellar fractures with good clinical results[3]. Biomechanical studies[4,5]demonstrated the advantage of this method over other forms of internal fixation. Since then, despite the many surgical options available, the Kirschner tension band technique has remained largely the gold standard in the treatment of patellar fractures[6]. The effectiveness of using two vertical Kirschner pins in combination with anterior 8 tension band fixation for patellar fractures has also been widely demonstrated in clinical practice.

With the development of the tension band technique, more and more patients with patellar fractures are being treated with the tension band technique. However, the limitations of the tension band technique are becoming increasingly apparent. In addition to the usual surgical complications such as infection, non-union and delayed healing of the fracture, the skin is irritated due to the superficial nature of the patellar and the protrusion of the wire used to loop the patellar as well as the end of the Kirschner needle[1,7,8]. And the tension band is not strong enough to support the patient's early functional exercise, causing complications such as stiffness and pain in the knee joint. Functional exercise causes complications such as breakage and withdrawal of the internal fixation, or even freeing and displacement into the joint, resulting in traumatic arthritis. Various reasons have created the need for secondary surgery of the patellar tension band[9-12].

In order to avoid complications with patellar tension bands, surgeons are constantly improving their techniques and investigating new fixation techniques. These include tension band construction with cannulated screws, basket plates, lag screws, anterior mesh plates and cerclage wiring[11,13-15]. However, these methods have certain indications, some cannot be used for comminuted displaced fractures and some still do not avoid the complications caused by tension bands. Some studies [16] have used sutures instead of tension bands to fix the patellar with good clinical results, but the stability of the sutures needs further study.

We have therefore modified the wire tension band technique by using a wire loop with an anterior "8" tension band for the treatment of comminuted displaced patellar. The aim of this study was to investigate the clinical efficacy of the modified wire tension band technique in the treatment of comminuted displaced patellar fractures.

Materials and methods

The study was approved by our ethics committee and all patients gave their informed consent and signed the informed consent form. A number of 97 patients with unilateral comminuted displaced patellar fractures from January 2015 to December 2021 were retrospectively analyzed at our institution. All patients had a closed patellar fracture caused by direct violence. X-ray and CT imaging of the affected knee were performed on admission to guide the surgical approach. All patients were treated with open reduction internal fixation and X-ray was performed intraoperatively and postoperatively. Patients were followed up regularly after surgery for clinical outcomes such as imaging and knee function.

Patient selection

Patient inclusion criteria (1) Unilateral closed comminuted patellar fracture with ≥ 3 fracture fragments; (2) Displacement of joint surfaces ≥ 2mm;(3) Severe damage to the knee extension device, severely affecting knee flexion and extension movement;(4) Age ≥ 18 years. Patient exclusion criteria: (1) Chronic patellar fracture (more than 3 weeks after injury); (2) Patients with open injuries or combined vascular or neurological injuries or other fractures; (3) Patient age < 18 years; (4) Patients with co-morbidities that cannot tolerate surgery; (5) Patients who refuse surgical treatment.

Operative technique

All patients were positioned in a lying position and general anaesthesia with tracheal intubation was chosen. All operations are performed by the same team of surgeons. A tourniquet is routinely applied preoperatively to the proximal thigh of the affected side. A longitudinal incision was made in the anterior median patellar and the skin and subcutaneous tissues were opened in turn to expose the patellar fracture. The fracture was confirmed intraoperatively as a comminuted fracture and was temporarily stabilized with a repositioning forceps. For severe comminuted fractures, a Kirschner pin or point repositioning forceps can be used to temporarily fix the comminuted fracture, which will convert the comminuted fracture into a simple fracture and restore the flatness of the articular surface. Larger fractures can sometimes be fixed with hollow screws. Intraoperative fluoroscopy is performed with the aid of a C-arm, ultimately to achieve stable temporary fixation of the fracture fragment.

In the MW group, we chose the location of the intersection of the horizontal midline of the patellar with the medial and lateral margins as the entry point. The two wires are threaded through the entry point and up or down along the edge of the patellar to the opposite side. The wire is placed as tightly as possible against the peripatellar tendinous tissue, preferably at the tendon bone junction. The wire is threaded through the four corners of the inner top, outer top, inner bottom and outer bottom respectively leaving a closed loop which is temporarily clamped with pliers for use. We take the third wire and thread it through either the medial or lateral two closed loops. The free end of the wire crosses in front of the patellar to form a transverse "8", which then passes through two other closed loops.

Once the three wires have been placed, we tighten the first two wires evenly and symmetrically. During the tightening process you can touch the joint surface with your fingers at the inner and outer support straps to keep the joint surface flat. When the wire is tightened and the wire is twisted to form a knot, both sides are twisted simultaneously or alternately with fewer adjustments. The assistant tightens the "8" wire in front of the patellar to create the right tension in the wire tension band to stable the fracture end and then tightens the two free ends into a knot (Fig. 1). The unnecessary wire is removed and the stump of the remaining wire knot is then turned towards the patellar and tapped appropriately to keep it close to the surface of the patellar and reduce the possibility of postoperative protrusion of the internal fixation. Reliable fracture and internal fixation position and flatness of the articular surface are demonstrated by C-arm fluoroscopy; and the stability of the internal fixation and fracture end is reliable when the knee is moved passively. The "8" wire end knot is positioned close to the ipsilateral wire knot to enable easy removal of the internal fixation with a small incision. In fact, the modified tension band technique still works well in comminuted fractures of the inferior pole of the patellar (Fig. 2). Depending on the type of fracture, we choose to use a transverse or longitudinal "8" tension band and can combine a Kirschner pin with a hollow screw (Fig. 3).

In the KW group, after temporary stabilization of the fracture, two Kirschner pins were threaded parallel from the superior pole of the patellar to the inferior level. The tension band wire is wrapped around the ends of the two Kirschner pins and fixed in an "8" position in front of the patellar. The ends of the wire are pulled evenly and firmly and knotted. Fluoroscopy shows a stable fracture end and internal fixation with a flat articular surface. The ends of the wire are pulled evenly and firmly and knotted. Cut off the remaining wire and the end of the Kirschner needle by an appropriate amount and bend the end.

Pre-operative and post-operative management

Pre-operative X-ray and CT of the affected knee will be completed in order to prepare a surgical plan. The operation time is recorded as the time between the incision of the skin and the closure of the incision. Intraoperative blood loss, operating time and intraoperative fluoroscopy time are recorded and analyzed. All patients had X-rays reviewed on the first post-operative day and were instructed to start functional exercises (Fig. 4). Patients were followed up with radiographs at 1, 3, 6 and 9 months after surgery to assess fracture healing. Clinical outcomes such as pain level and knee mobility were recorded at the last follow-up and analyzed using VAS and Böstman scores. Complications such as traumatic arthritis, wound infection, non-healing bone, failure of internal fixation and fracture during treatment were recorded and compared between the two groups. The internal fixation is removed after the fracture has healed for about 1 year after surgery.

Statistical analysis

We used IBM SPSS Statistics 23.0 statistical software to analyze the data. Parametric data such as age, operative time, fluoroscopy time, blood loss, length of stay, etc. are described as mean ± standard

deviation and t-tests are used for comparison between groups. Comparisons of proportional values were applied using $\chi 2$ analysis or Fisher's exact test. P-value ≤ 0.05 is the level of statistical significance.

Results

The 97 patients who met the inclusion criteria included 58 with a modified wire tension banding technique (MW); the other 39 had a Kirschner needle tension banding technique (KW). There was no significant difference between the two groups in terms of age, gender, BMI, history of smoking and alcohol consumption, or length of hospital stay. All patients underwent surgery within 48 hours of hospital admission. All patients included 52 males and 45 females (Table 1). In the MW group the mean age of the patients was at 39.02 ± 11.91 (range 18–64); in the KW group the mean age of the patients was at 38.08 ± 11.67(range 19–63). There was no statistically significant difference between the two groups in terms of age (P = 0.702). There were 35 males and 23 females in the MW group and 21 males and 18 females in the KW group, with no statistical significance between the two groups in terms of gender(P = 0.525). The mean BMI of the MW group was 24.24 ± 2.01(range 20.28–29.07) and the mean BMI of the KW group was 24.94 ± 2.18(range 20.57–29.36), with no statistically significant difference between the two groups(P = 0.103). In the MW group, there were 15 cases of tobacco and alcohol history, 22 left patellar fractures and 18 traffic injuries; in the KW group, there were 8 cases of tobacco and alcohol history, 15 left patellar fractures and 13 traffic injuries. There were no significant differences between the two groups in alcohol and tobacco history(P = 0.544), affected limb(P = 0.958) and injury mechanism (P = 0.812). The postoperative follow-up time was 13.36 ± 1.79(range 10–17) in the MW group, and the postoperative follow-up time was 13.53 ± 2.29(range 10–18) in the KW group, and there was no significant difference in the postoperative follow-up time between the two groups(P = 0.642). The operation time is from the start of the incision to the close of the suture (Table 2). The operation time was 49.91 ± 3.88(range 43–57) in MW group and 67.64 ± 4.27(range 60–75) in KW group. There was significant statistical difference between the two groups (P < 0.05). The intraoperative blood loss in MW group 102.59 ± 10.01 (range 90–120) was significantly less than that in KW group 126.41 ± 13.86(range 110–160) (P < 0.05). The fluoroscopy time in MW group 8.14 ± 1.82(range 6–12) was significantly less than that in KW group 10.41 ± 1.67(range 8–14), and the difference was statistically significant (P < 0.05). The hospital days in MW group 6.07 ± 1.23(range 3–9) were also significantly less than that in KW group 6.79 ± 1.42(range 5–10) (P < 0.05). All patients achieved good healing after operation. The fracture healing time was 3.83 ± 1.35(range 3–6) in MW group and 4.08 ± 1.46 (range 3–6)in KW group, and there was no significant difference between the two groups (P = 0.390). However, two patients in each group were found to have wire fracture when the X-ray was reviewed before removal of the internal fixation. At last follow-up, the knee ROM of patients in MW group was 125.12 ± 4.38(range 116–134). The knee ROM of the KW group was 27.95 ± 1.34(range 114–133), and there was no significant difference between the two groups(P = 0.100). The Böstman scale was 28.33 ± 1.08(range 26–30) in the MW group and 27.965 ± 1.34 (range 26–30) in the KW group. There was no significant difference between the two groups (P = 0.128). The WAS score of MW group WAS 1.14 ± 0.96(range 0–3), and the VAS score of KW group WAS 1.28 ± 1.08(range 0–3), and there WAS no significant difference between the two groups (P = 0.492).

According to Böstman score, there were 38 cases of excellent and 10 cases of good in MW group; In KW group, 23 cases were excellent and 8 cases were good. There was no significant difference in the excellent and good rate between the two groups (P = 0.684) (Table 3). The Böstman score of postoperative patients showed that at 3 months after operation, the score of MW group was 27.07 ± 0.79(range 26–28), and the score of KW group was 26.85 ± 0.75(range 26–28). There was no significant difference between the two groups. However, at 6 months after operation, the Böstman score of MW group was 27.97 ± 0.94(range 26–30), and that of KW group was 27.23 ± 0.87(range 26–29). Before removal of internal fixation, the Bostman score of MW group was 28.19 ± 0.98(range 26–29), and that of KW group was 27.31 ± 0.89(range 26–30). There was significant difference between the two groups (Table 4).

Discussion

There is a lot of research on the treatment of patellar fractures, but the choice of treatment and internal fixation for comminuted displaced patellar fractures is still controversial. Whichever treatment option is chosen, the aim should be achieving anatomical repositioning, levelling of the joint surface, stable fixation and early functional exercise. Although it has been shown that partial patellectomy in distal patellar comminuted fractures with difficult anatomical repositioning provides good long-term clinical outcomes, it results in loss of patellar height and loss of knee range of motion[17]. In simple transverse and longitudinal patellar fractures, fixation with Kirschner pins or hollow screws can be achieved with minimal invasion and fixation[18]. Some study [19] used low profile mesh plates to treat comminuted displaced patellar fractures with good clinical outcomes. Although some studies[1,20,21] have used patellar claws and angular plates in patellar fractures with good results, the inevitable limitations of soft tissue irritation, internal fixation failure and the need for secondary surgical removal.

The tension band technique is widely used for patellar fractures with good clinical outcomes and is considered the gold standard for the treatment of patellar fractures[22,23]. With the extensive use of tension banding techniques and the continuous development of innovative fracture fixation techniques, many studies have been conducted to improve the tension band technique. Some studies[12,24] have used two parallel Kirschner wires or hollow screws through the fracture plane in combination with a wire tension band to fix patellar fractures. However, this can only be used for simple patellar fractures. Chong Zhang[25] et al. used a modified double tension band technique to treat patellar fractures, with a lower complication rate and better clinical outcomes for early activity compared to the AO tension band technique. To avoid the complications associated with the Kirschner pins, a wire loop is used to fix the patellar. However, the indications for treating patellar fractures are still limited[26]. Mengcun Chen[16] et al. show better intraoperative and early postoperative clinical results of displaced comminuted patellar fractures using the Nice Knot as an assisted reduction but lacked analysis of the stability of fixation with sutures and long-term results. A study[27] on the treatment of comminuted displaced patellar fractures by means of a modified cerclage wiring technique achieved more satisfactory clinical results. Despite the complications

of the wire tension band technique, it is still the most commonly used method of treating patellar fractures[28].

We have modified the wire tension band by combining the traditional figure-of-8 tension band with a cerclage wire to allow for both the application of comminuted patellar fractures and the increased stability of the cerclage wire[29,30]. In contrast to traditional cerclage wire and anterior patellar "8" tension bands, we use three wires for fixation. Two wires are threaded through the upper and lower poles of the patellar and then another wire is used to connect the upper and lower wires. The three wires are looped together, and when the knots are tightened on both sides, the forces are more even and symmetrical. Either horizontal or vertical "8" rows can be fixed in the tension band. We found that the Böstman score was significantly better in the modified tension band group than in the Kirschner wire tension band group during the period from the sixth month after surgery to the time before the removal of the internal fixation. This may be related to the irritation of the Kirschner wire tension band to the skin and soft tissue, leading to local discomfort of the patient

Our modified wire tensioning technique is more widely used in the management of comminuted patellar fractures or other fracture types other than avulsion fractures of the upper and lower poles of the patellar. Our modified wire tensioning technique is more widely used in the management of comminuted patellar fractures or other fracture types other than avulsion fractures of the upper and lower poles of the patellar, which provide reliable clinical results, less destruction of soft tissue and blood flow, no significant endophytic irritation, simple operation, low cost, allows early functional exercise and few postoperative complications. It should be observed that the internal fixation needs to be removed 6 months to 1 year after the fracture has healed to avoid fracture of the internal fixation or freeing of the fractured internal fixation into the joint cavity under prolonged stress conditions. The internal fixation can be removed by simply making two small incisions of approximately 1.5cm in length on both sides of the Patellar where the wires are knotted, further reducing the likelihood of incision infection during internal fixation removal. The use of this modified wire tension band technique for fixation of patellar fractures not only combines the biomechanical advantages of the traditional AO/ASIF internal fixation technique, but is also more widely used for comminuted patellar fractures, allowing early functional exercise and reducing complications for the patient.

Although our data show good clinical outcomes in terms of operative-related factors as well as postoperative follow-up results, there are still some shortcomings in this study: 1. This study is a single-centre retrospective clinical case analysis with a low level of evidence and a small number of cases, therefore a multi-centre, large sample case analysis is needed to confirm the results of this study. 2. The study was not randomly grouped and the variables were not unique, with some selection bias.3. Although the clinical and imaging results are good, more long-term follow-up results are needed to determine if there are long-term complications.

Conclusion

In conclusion, the modified wire tension band technique for fixation of patellar fractures is an effective new technique for the safe and reliable management of patellar fractures and offers an alternative strategy for the treatment of patellar fractures.

Declarations

Ethics approval and consent to participate: The experimental protocol was established, according to the ethical guidelines of the Helsinki Declaration and was approved by the Human Ethics Committee of Shandong Provincial Hospital Affiliated to Shandong First Medical University. Written informed consent was obtained from each study participants.

Consent for publication: Not applicable.

Availability of data and materials: All data generated or analyzed during this study are included in this published article.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: HLF and YYL conceived of the presented idea. HFN wrote the main manuscript text. HFN and HSM prepared figures and tables. All authors reviewed the manuscript.

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Tables

Table 1 Patient demographics

Group	MW	KW	P
No. of cases	58	39	-
Gender (M/F)	35/23	21/18	0.525
Age (Year, mean±SD)	39.02±11.91	38.08±11.67	0.702
BMI	24.24±2.01	24.94±2.18	0.103
History of tobacco and alcohol (Y/N)	15/43	8/31	0.544
Left or right (L/R)	22/36	15/24	0.958
Injury mechanism(T/F)	18/40	13/26	0.812
Follow-up time	13.34±1.79	13.53±2.29	0.642

M, F, BMI, SD, (Male, Female, Body Mass Index, Standard deviation)

Table 2 Operation related factors

Group	MW	KW	P
Operative time (min, mean±SD)	49.91±3.88	67.64±4.27	0.05
Blood loss (ml, mean±SD)	102.59±10.01	126.41±13.86	0.05
Fluoroscopy time (s, mean±SD)	8.14±1.82	10.41±1.67	0.05
Hospitalization days(d, mean±SD)	6.07±1.23	6.79±1.42	0.05

SD, (Standard deviation)

Table 3 Postoperative follow-up results

Group	MW	KW	P
Fracture healing time (month, mean±SD)	3.83±1.35	4.08±1.46	0.390
Complication	2	2	-
ROM (mean±SD)	125.12±4.38	123.56±4.75	0.100
Böstman scale (mean±SD)	28.33±1.08	27.95±1.34	0.128
VAS(mean±SD)	1.14±0.96	1.28±1.08	0.492
Rate of the Böstman score	10/48	8/31	0.684

ROM, VAS, SD, (Range of motion, Visual analogue scale, Standard deviation)

Table 4 Böstman scale

Group	MW	KW	P
3M (month, mean±SD)	27.07±0.79	26.85±0.75	0.167
6M(month, mean±SD)	27.97±0.94	27.23±0.87	0.05
Pre-op (mean±SD)	28.19±0.98	27.31±0.89	0.05
Post-op (mean±SD)	28.33±1.08	27.95±1.34	0.128

SD, (Standard deviation)

Figures

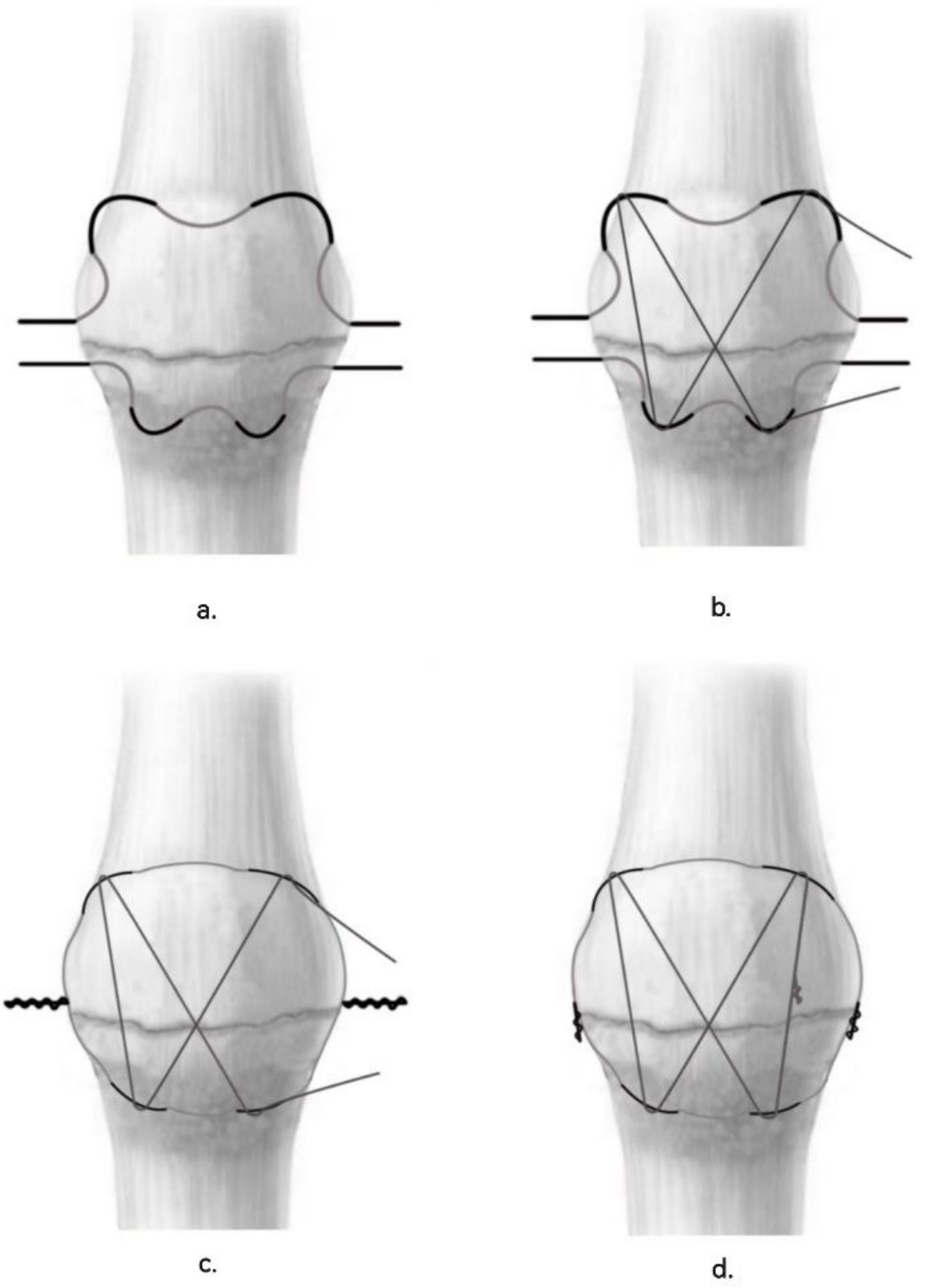

Figure 1

Illustration of a modified wire tension band technique for treatment of comminuted displaced patella fractures. (a). The two wires are threaded up or down along the edge of the patella to the opposite side and leave four loops at the four corners. (b). The third wire passes through the four closed loops and crosses in front of the patella to form a transverse "8". (c). The first two wires are tightened evenly and symmetrically and twisted into a knot. (d). The assistant tightens the "8" wire in front of the patella to create the right tension in the wire tension band to stable the fracture end and then tightens the two free ends into a knot.

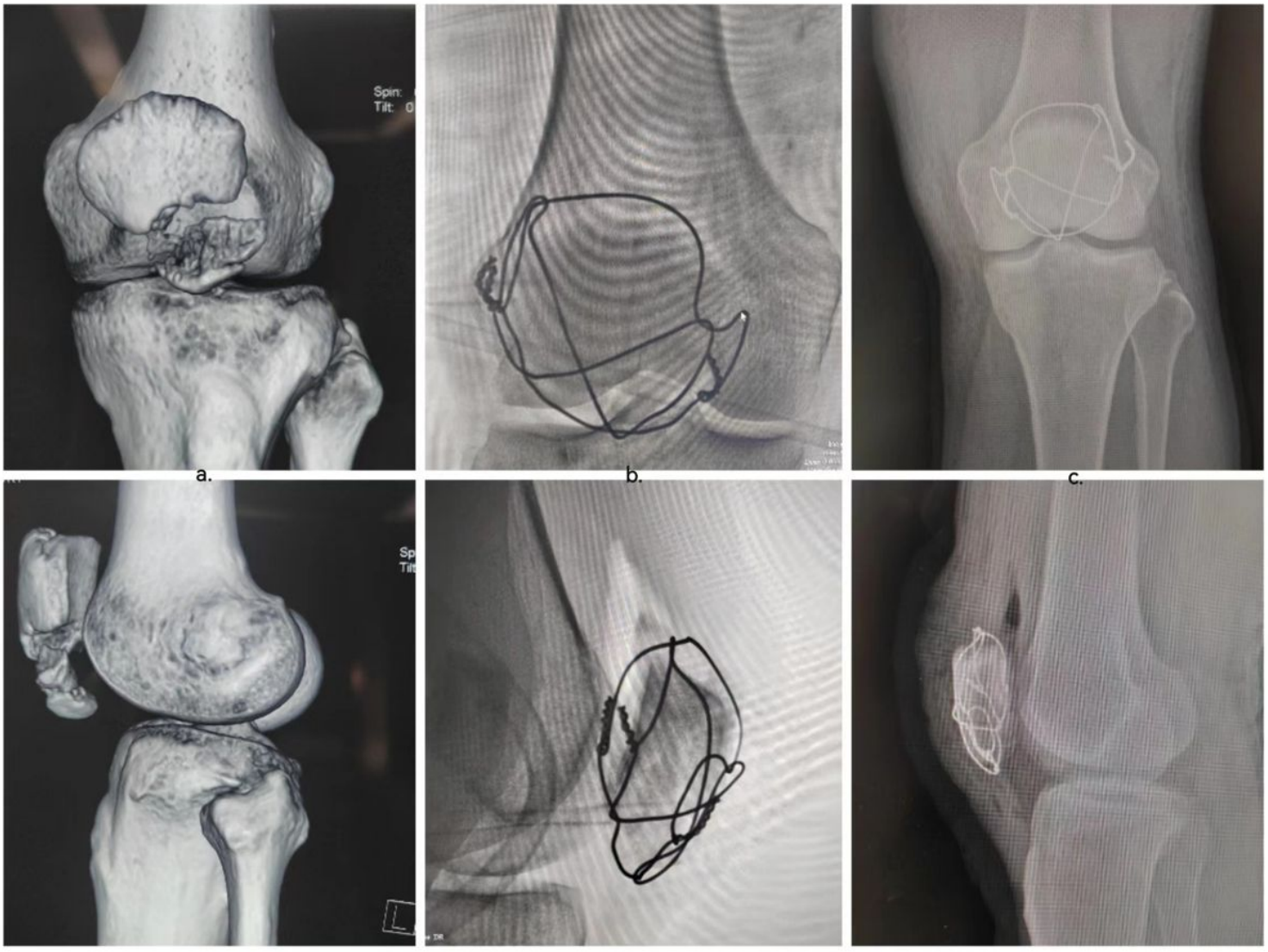

Figure 2

Combination of modified wire tension band with hollow screws and Kirschner pins. (a). Pre-operative CT evaluation and measurement of patella fracture. (b). Intraoperative fluoroscopy showing internal fixation of patella fracture. (c). Postoperative fluoroscopy showing internal fixation of patella fracture

Figure 3

Longitudinal “8” tension band. (a/b). Pre-operative X-ray evaluation and measurement of patellar fracture. (c/d). Stabilisation of transverse patellar fractures using the anterior patellar longitudinal longitudinal “8” tension band.

Figure 4

Follow-up of patients. (a). Pre-operative X-ray and CT evaluation and measurement of patella fracture. (b). Fracture healing at the last post-operative follow-up. (c). Removal of internal fixation after the patient's fracture has healed. (d). Patient's post-operative functional exercise.