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Krackow suturing combined with the double-loop tension-reducing suture versus Kirschner-wire tension band for the treatment of inferior pole patella fracture

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Abstract

Background

Inferior pole patellar fractures compromise the knee extensor mechanism and require stable fixation to permit early rehabilitation. Kirschner-wire tension band technique (KBW technique) remains widely used but is associated with fixation failure and implant-related complications, particularly in comminuted fractures. This study aimed to compare the clinical and radiological outcomes of the Krackow suturing combined with double-loop tension-reducing technique (KDL technique) with those of the conventional KBW technique for the treatment of inferior pole patellar fractures.

Methods

A retrospective comparative study was conducted involving 44 patients with AO/OTA type 34-A1 inferior pole patellar fractures treated between January 2022 and December 2024. Twenty-one patients underwent the KDL technique, and 23 patients were treated with KBW technique. Clinical outcomes included knee range of motion, Böstman score, complications, and reoperation rate. Radiological evaluation included the Insall–Salvati index (ISI) measured immediately postoperatively and at final follow-up. Statistical analyses were performed to compare outcomes between groups.

Results

Baseline demographic characteristics were comparable between groups. At final follow-up, the KDL group demonstrated significantly greater knee flexion ($128.05 \pm 3.23°$ vs. $119.56 \pm 10.54°$, $P = 0.001$) and higher Böstman scores (28.52 ± 1.33 vs. 26.91 ± 2.30, $P = 0.015$) than the KBW group. The final ISI was significantly higher in the KDL group (0.92 ± 0.14 vs. 0.78 ± 0.14, $P = 0.002$), with a smaller postoperative decline in patellar height. The overall complication rate was significantly lower in the KDL group (9.5% vs. 39%, $P = 0.026$), and no reoperations were required, compared with a 60.9% reoperation rate in the KBW group ($P < 0.001$). All fractures achieved union without infection or patellofemoral arthritis.

Conclusions

The KDL technique may provide stable fixation for inferior pole patellar fractures and was associated with improved postoperative knee flexion and lower complication and reoperation rates compared with the KBW technique.

Introduction

The inferior pole of the patella refers to the distal approximately one-quarter of the patella that is not covered by articular cartilage. Fractures involving this region represent a distinct subtype of extra-articular patellar fractures, accounting for approximately 5%–22.4% of all patellar fractures [1], and are classified as type 34-A1 according to the Orthopaedic Trauma Association/AO (OTA/AO) classification system. The inferior pole of the patella serves as the attachment site of the patellar tendon and plays a critical role in transmitting quadriceps muscle force. It constitutes an essential component of the knee extensor mechanism. Therefore, the integrity of the inferior patella is crucial for maintaining normal knee joint function. Displaced fractures of the inferior pole of the patella should be managed surgically at an early stage. The primary objectives of surgical treatment for inferior pole patellar fractures are to restore the continuity of the extensor mechanism as early as possible and to allow early initiation of knee rehabilitation, thereby maximizing the recovery of knee function.

Traditional surgical concepts have regarded the inferior pole of the patella as a fracture fragment to be anatomically reduced and stabilized using various internal fixation devices. The classic fixation method is the Kirschner wire tension band technique, which provides satisfactory fixation for fractures with an intact inferior pole fragment. However, this technique has limited ability to achieve stable fixation in comminuted inferior pole fractures and is associated with a relatively high incidence of complications [2]. To achieve more robust fixation of inferior pole patellar fractures, several patella-specific implants have been developed, including the basket plate [3], mesh plate [4], rim plate [5], and lateral rim variable-angle locked plating system [6]. Although these specialized plates provide strong fixation, their high cost limits widespread application, and they are associated with a relatively high rate of complications, such as implant irritation and patellar tendon injury. In an effort to achieve stable fixation while minimizing implant-related irritation, some authors have adopted the separate vertical wiring technique for the treatment of inferior pole patellar fractures, with satisfactory clinical outcomes reported [7]. However, this technique is technically demanding and requires a high level of surgical expertise.

Emerging surgical concepts consider the inferior pole of the patella as a continuation of the patellar tendon rather than merely a fracture fragment, and emphasize restoration of the continuity of the knee extensor mechanism using high-strength sutures. A more radical approach is excision of the inferior pole of the patella with patellar tendon reconstruction [8]. However, owing to the prolonged tendon–bone healing time and the need for extended postoperative immobilization, this technique is associated with a high incidence of knee stiffness and patella baja, and is therefore generally reserved for complex inferior pole fractures, nonunion, infection, or revision cases [1]. Preservation of the inferior pole of the

patella allows for solid bone-to-bone healing, which is more favorable for early rehabilitation. Some authors have reported the use of suture anchor fixation for inferior pole patellar fractures; however, the high cost of suture anchors increases the financial burden on patients [9]. Other investigators have employed Krackow suturing combined with transosseous patellar tunnel techniques to treat inferior pole patellar fractures. This method is cost-effective, provides high biomechanical strength [10], and yields satisfactory functional outcomes. Nevertheless, complications such as suture rupture, fixation loosening, increased fracture gap, and fixation failure have still been reported. Consequently, contemporary approaches often combine the Krackow suture technique with additional augmentation methods to enhance fixation strength. Richard et al. [11] reinforced Krackow suturing with a titanium cable cerclage technique, whereas Yan et al. [12] combined Krackow suturing with a suture-bridge technique. In the present study, we employed Krackow suturing combined with a double-loop tension-reducing technique (KDL technique) for the treatment of inferior pole patellar fractures.

Methods

Patient enrollment

A retrospective, single-center study analysis was performed on patients who were hospitalized for the treatment of inferior pole patellar fractures at our institution between January 2022 and December 2024. Patients meeting the inclusion criteria were identified through the electronic medical record system, and those fulfilling the exclusion criteria were subsequently excluded. Inclusion criteria were as follows: patients diagnosed with inferior pole patellar fractures between January 2022 and December 2024 who (1) had fractures confirmed by imaging studies and classified as AO/OTA type 34-A1; (2) were aged between 20 and 65 years at the time of presentation; (3) underwent surgical treatment performed by the same primary surgeon; and (4) were treated using either the tension band wiring technique (KBW technique) or the KDL technique. Exclusion criteria included: (1) open fractures; (2) severe concomitant injuries involving other knee-associated structures, such as tibial plateau fractures, femoral condyle fractures, cruciate ligament ruptures, or meniscal tears; (3) incomplete clinical data; (4) pre-existing knee pain or limitation of knee range of motion prior to injury; (5) revision surgery cases; and (6) loss to follow-up or a follow-up duration of less than 1 year.

Following the above inclusion and exclusion criteria, a total of 44 patients were enrolled in this study (Fig. 1). The sample size was determined by the number of patients meeting the inclusion and exclusion criteria during the study period. According to the surgical technique, patients were divided into two groups: the first group comprised 21 patients who underwent the KDL technique, while the second group comprised 23 patients who underwent the Kirschner-wire tension band technique (KBW technique). The choice of

surgical technique was determined through discussion between the surgeon and the patient, with patients being fully informed of the associated risks and potential benefits. This study was approved by the Institutional Ethics Committee of our hospital.

Surgical Techniques

The KBW technique represents a classic surgical approach. In addition to fracture fixation, absorbable sutures are used to approximate the fascial layers over the fracture fragments to stabilize smaller fragments.

The key steps of the KDL technique are as follows: 1. Bone tunnel creation: Three longitudinal, parallel patellar tunnels were created using a 2 mm Kirschner wire at the central, mediomedial one-third, and mediolateral one-third of the patella. A transverse patellar tunnel was then drilled 1 cm proximal to the fracture line using a 3-mm Kirschner wire, taking care to avoid alignment with the longitudinal tunnels in the same coronal plane. Two 2 mm tibial tunnels were created horizontally 1.5 cm posterior to the tibial tubercle. The tunnel openings were smoothed to remove sharp edges and prevent suture cutting. 2. Krackow suture: No. 5 Ethibond sutures were used to perform Krackow stitches on the medial and lateral portions of the patellar ligament. The free ends of the sutures were sequentially passed through the distal patellar fracture fragment and the patellar bone tunnels. With the knee flexed at 30°, the Krackow sutures were tightened and tied to achieve secure fixation (Fig. 2a). 3.Distal patellar cerclage: The No. 5 Ethibond suture was doubled and passed from the lateral opening to the medial opening of the patellar tunnel, looped around the distal medial patellar margin, passed under the patellar ligament along the inferior patellar surface, and brought out on the lateral patellar surface (Fig. 2b). with the knee in full hyperextension, the suture was tightened using a Nice knot on the medial side to complete the distal patellar cerclage (Fig. 2c). 4. Patella–tibial tubercle tension-reducing loop: Two double-stranded 0# PDS sutures were introduced through the lateral and medial entries of the transverse patellar tunnel. The first suture passed through the tibial tunnel on the same side and was secured with a Nice knot to form a “0”-shaped loop (Fig. 2d). The second suture was passed through the opposite side of the tibial tunnel and tied with a Nice knot to form a figure-of-8 loop (Fig. 2e). Both Nice knots were tied simultaneously with the knee in full extension (Fig. 2f).

Rehabilitation and Follow-up

KDL group

Rehabilitation began on postoperative day 1. Patients performed bedside leg-lowering exercises three times daily, 30 minutes per session (Fig. 3a), with 2–3 repetitions of slow,

passive knee flexion and extension per session. Knee range of motion (ROM) reached 90° within the first 3 weeks. From week 3, patients performed wall-slide exercises three times daily for 30 minutes each (Fig. 3b), achieving a knee ROM of 110° by 6 weeks postoperatively. After 6 weeks, patients continued daily exercises of the same duration, including either seated knee-hug exercises (Fig. 3c) or supine leg-lowering exercises (Fig. 3d), with knee ROM exceeding 110° by 8 weeks. After 8 weeks, patients were allowed to perform functional exercises, including wall-supported squats and stair climbing. Radiographic assessment of the knee (anteroposterior and lateral views) was performed on postoperative day 1. Outpatient follow-up visits were scheduled at 6 and 8 weeks to guide functional exercises. At 1 year postoperatively, patients were evaluated in the outpatient clinic for knee flexion and extension ROM, completed the Böstman score, underwent anteroposterior and lateral knee radiographs, and the Insall-Salvati index (IS index) was measured on lateral radiographs with the knee flexed at 30°.

KBW group

Postoperatively, the knee was immobilized with a hinged knee brace, allowing passive knee flexion and extension from 0° to 60° during the first 3 weeks. After 3 weeks, rehabilitation followed the same protocol as in the KDL group, including bedside leg-lowering exercises, wall-slide exercises, seated knee-hug or supine leg-lowering exercises, wall-supported squats, and stair-climbing exercises.

Statistical Analysis

Continuous variables were tested for normality. Normally distributed data were compared using the independent-samples t-test, while non-normally distributed data were analyzed using the Mann–Whitney U test. Paired continuous data were analyzed using the paired t-test or the Wilcoxon signed-rank test, as appropriate. Categorical variables were compared using the chi-square test or Fisher’s exact test. All tests were two-sided, and a p-value < 0.05 was considered statistically significant.

Results

A total of 44 patients with inferior patellar fractures were included in this study, with 21 patients undergoing the KDL procedure and 23 patients undergoing the KBW procedure. Demographic characteristics were comparable between the two groups (Table 1).

Table 1
Comparison of patient demographics across the study groups

Gender	**Group KDL**	**Group KBW**	**P**
			0.349#
Male	13(61.9%)	11(47.8%)	
Female	8(38.1%)	12(52.2%)	
Age(years)	52.0(58.5–36.0)	52.0(55.0–37.0)	0.841###
Fracture pattern			0.862#
Simple	16(76.2%)	17(73.9%)	
Comminution	5(23.8%)	6(26.1%)	
BMI (Kg/m^2)	24.7 ± 1.6	24.0 ± 1.5	0.169##
Left/right Limbs			0.537#
Left	12(57.1%)	11(47.8%)	
Right	9(42.9%)	12(52.2%)	

KDL technique: Krackow and double-loop technique; KBW technique: Kirschner-wire tension band technique. # Based on chi-square test; ## Based on independent-samples T test; ### Based on Mann-Whitney U-test.

Clinical Outcomes

Clinical outcomes showed no significant differences between the two groups in terms of final knee extension angle ($1.48 \pm 0.54°$ vs. $1.72 \pm 0.61°$, $P = 0.176$), operative time (73.76 ± 4.33 min vs. 74.17 ± 4.25 min, $P = 0.752$), length of hospital stay (10.24 ± 3.46 d vs. 10.96 ± 3.48 d, $P = 0.464$), or immediate postoperative IS index (0.94 ± 0.14 vs. 0.91 ± 0.13, $P = 0.422$).

Significant differences were observed in the final knee flexion angle ($128.05 \pm 3.23°$ vs. $119.56 \pm 10.54°$, $P = 0.001$), Böstman score (28.52 ± 1.33 vs. 26.91 ± 2.30, $P = 0.015$), total hospitalization cost (11,409 [10,828–12,193] CNY vs. 12,111 [11,711–17,501] CNY, $P < 0.01$), final IS index (0.92 ± 0.14 vs. 0.78 ± 0.14, $P = 0.002$), and the change in IS index from immediate postoperative to final follow-up in both the KDL group (0.94 ± 0.14 vs. 0.92 ± 0.14, $P = 0.014$) and KBW group (0.91 ± 0.13 vs. 0.78 ± 0.14, $P < 0.01$) (Table 2).

The incidence of complications was significantly lower in the KDL group compared with the KBW group (9.5% vs. 39%, $P = 0.026$), and none of the KDL group patients required

reoperation (0% vs. 60.9%, $P < 0.001$). In the KDL group, two complications were reported: knee extension weakness ($n = 1$) and joint friction sensation ($n = 1$). In the KBW group, nine complications were reported: implant irritation ($n = 7$), wire migration ($n = 1$), and knee extension weakness ($n = 1$). All fractures achieved union, and no infections or patellofemoral arthritis were observed during the follow-up period.

Figure 4 shows a representative case from the KDL group, and Fig. 5 illustrates a typical case of wire migration in the KBW group.

Table 2
Comparison of postoperative outcomes across the study groups

Follow-up (months)	**Group KDL** 14.67 ± 1.85	**Group KBW** 14.91 ± 2.04	**P** $0.678^{\#\#}$
Range of motion at final follow-up (degree°)			
Extension	1.48 ± 0.54	1.72 ± 0.61	$0.176^{\#\#}$
Flexion	128.05 ± 3.23	119.56 ± 10.54	$0.001^{\#\#}$
Böstman score(final follow-up)	28.52 ± 1.33	26.91 ± 2.30	$0.015^{\#\#\#}$
Operation time (minutes)	73.76 ± 4.33	74.17 ± 4.25	$0.752^{\#\#}$
Length of Stay (days)	10.24 ± 3.46	10.96 ± 3.48	$0.464^{\#\#\#}$
Hospital expenses at final follow-up (yuan)	11409 (12193 − 10828)	12111 (17501 − 11711)	$< 0.01^{\#\#\#}$
Insall-Salvati index (ISI)			
Immediate postoperative ISI	0.94 ± 0.14	0.91 ± 0.13	$0.422^{\#\#}$
Final follow-up ISI	0.92 ± 0.14	0.78 ± 0.14	$0.002^{\#\#}$
P value	0.014*	< 0.01*	
Reoperation rate	0	14/23(60.9%)	$< 0.01^{\#}$
Complications	2(9.5%)	9(39%)	$0.026^{\#}$
Implant Irritation	0	7	
Wire slipped out	0	1	
Knee extensor weakness	1	1	
Joint crepitus	1	0	

KDL technique: Krackow and double-loop technique; KBW technique: Kirschner-wire tension band technique. # Based on Fisher's exact test; ## Based on Independent-samples T test; ### Based on Mann-Whitney U-test; * Based on Paired samples t-test.

Discussion

The distal patella has relatively thin bone and is subjected to high tensile forces during knee extension. Consequently, it is prone to comminuted fractures following trauma. Inferior patellar fractures fixed with tension-band wiring using Kirschner wires (K-wires) are at high risk of postoperative displacement, with reported reoperation rates ranging from 20% to 50% [13]. The advent of high-strength sutures has made it feasible to stabilize inferior patellar fractures by suturing the patellar ligament. Several experts have achieved satisfactory outcomes using suture-anchor fixation for distal patellar fractures [1, 13]. However, anchor fixation inevitably increases the economic burden on patients. Compared with anchor fixation, suture-based fixation of the patellar ligament through bone tunnels represents a more cost-effective alternative. In 1986, Krackow [14] first described the use of bone tunnels to repair ruptured patellar ligaments, achieving favorable clinical outcomes. This technique was subsequently applied to the fixation of distal patellar fractures. Compared with K-wire or plate fixation, the Krackow suture technique offers better postoperative function, reduced implant irritation, lower reoperation rates, and a smaller social and economic burden.

Nevertheless, the Krackow suture technique has limitations. Chih-Hsun Chang et al. [15] reported that it was an independent risk factor for fixation failure in inferior patellar fractures. In a cadaveric study, Krushinski and Erik M. demonstrated that even with pre-tensioned sutures, knee motion after Krackow suturing resulted in significant fracture gap formation, primarily at the suture-ligament interface. Richard et al. [11] confirmed in another cadaveric study that Krackow suturing alone led to widening of the fracture gap with repeated knee flexion and extension, ultimately causing extension lag. The combination of Krackow suturing with a titanium cable patella–tibial tension-reducing loop significantly reduced fracture gap formation, but required secondary surgery to remove the hardware, increasing patient discomfort and financial burden. Using high-strength sutures for reinforcement can avoid the need for reoperation. James et al. [12] reported that the suture-bridge technique reduced postoperative fracture gap formation and increased fixation strength. Fan et al. [16] applied the “Candy Box” technique on the basis of Krackow suturing and achieved satisfactory outcomes. Therefore, reinforcing the Krackow suture through bone tunnels with additional suture-based fixation can compensate for the inherent limitations of the technique.

In this study, the KDL technique provided satisfactory fixation of inferior patellar fractures. Krackow suturing was performed using No. 5 Ethibond. Joseph B. Norris [17] reported that 5# sutures have a lower risk of cut-through compared with 2# sutures, and that braided sutures of the same diameter can withstand higher tensile forces than Ethibond sutures. Knotting the Krackow suture with the knee flexed at 30° can prevent excessive tension on the patellar ligament. The distal patellar cerclage was performed with No. 5 Ethibond and secured with a Nice knot in knee hyperextension. Compared with

conventional surgical knots, the Nice knot provides better compression at the fracture site, thereby reducing the risk of fragment loosening.

In addition, this study employed a patella–tibial tension-reducing loop. Some reports have indicated suboptimal postoperative knee function following patella–tibial cerclage [18]. Kuo et al. [19] reinforced Krackow suturing with a patella–tibial cerclage but observed no improvement in knee ROM (mean 108°). In that study, the wire was looped over the superior patella rather than through a patellar bone tunnel, which may have altered the biomechanics of the knee extension apparatus and contributed to extension lag. Conversely, other studies support the use of patella–tibial cerclage. Li J et al. [20] compared a titanium cable tension-band group with a modified group that included patella–tibial cerclage and found that the modified group achieved greater flexion ROM ($111.33 \pm 13°$) compared with the titanium cable group ($98.21 \pm 21.70°$). Zhang Z. S. [21] reported satisfactory knee ROM ($117.3 \pm 6.9°$) using patellar cerclage combined with patella–tibial titanium cable cerclage. Kasten P et al. [22] compared 2 mm PDS sutures and wire for end-to-end patellar ligament repair with circumferential reinforcement at the tibial tubercle and reported favorable mid- and long-term outcomes.

Previous studies have reported that low-riding patella may occur after KBW fixation, which can increase patellofemoral joint pressure [23] and impair knee function [3]. Chih-Hsun Chang et al. [15] suggested that shortening of the tendon fibers leads to an immediate postoperative decrease in the IS index, and that implant-related irritation may induce further tendon fibrosis, potentially causing a further decline in the IS index. In the present study, we observed a reduction in the IS index at final follow-up in the KBW group compared with the immediate postoperative value, supporting the notion that implant irritation promotes additional patellar tendon fibrosis, resulting in a decreased IS index.

Furthermore, patella–tibial cerclage may also result in a low-riding patella. Kasten et al. [22] reported a decrease in the IS index following patella–tibial cerclage, and Zhang Z. S. et al. [21] reported a relatively high incidence of low-riding patella (27.3%) with patellar cerclage, which was a major cause of reoperation. In the present study, we consider that the possible causes of low-riding patella are: tightening the patellar and tibial fixation devices in full knee extension, which shortens the distance between the patella and tibial tubercle; and the use of rigid, nonabsorbable materials for patella–tibial fixation, which prevents spontaneous restoration of patellar height if low-riding occurs postoperatively. In our study, although the IS index decreased after patella–tibial cerclage, the decline was smaller than that observed in the KBW group. We performed patella–tibial cerclage with the knee flexed at 30° to avoid excessively low patellar positioning immediately postoperatively. Two double-stranded No. 0 PDS sutures (each strand 0.35–0.4 mm) were used for the cerclage to prevent further reduction in the IS index. This is attributable to the ideal tensile strength, excellent tissue compatibility, and prolonged degradation time

of PDS sutures. No. 0 PDS can maintain moderate tensile strength for approximately 6 weeks, providing sufficient support during early fracture healing to reduce stress at the fracture site and allow early passive knee flexion, while gradually degrading during the mid-to-late stages of healing to restore the physiological function of the patellar ligament and reduce the incidence of low-riding patella.

The KDL technique allowed patients to achieve greater knee flexion and higher Böstman scores compared with the traditional KBW fixation. Fixation of comminuted inferior patellar fractures using conventional KBW is challenging. Surgeons, concerned about loss of fracture reduction, tend to recommend delayed postoperative knee flexion exercises and prolonged use of auxiliary fixation [24], thereby missing the optimal window for functional rehabilitation. In contrast, surgeons using the KDL technique have less concern regarding loss of reduction, allowing patients to perform early knee flexion exercises with larger ranges of motion.

This study has several limitations. First, the relatively small sample size may have limited the statistical power and introduced potential bias. Second, as a retrospective, single-center study, inherent selection bias could not be completely avoided. In addition, the decrease in the Insall–Salvati (IS) index observed in the Kirschner wire fixation group during long-term follow-up may be related to implant-induced patellar tendon fibrosis; however, this speculation remains hypothetical and requires further validation through well-designed prospective studies, animal experiments, and detailed pathological analyses.

Conclusions

The Krackow and double-loop technique appears to provide stable fixation for inferior pole patellar fractures. In this retrospective, single-center cohort study, the KDL technique was associated with improved postoperative knee flexion and lower complication and reoperation rates compared with the KBW technique. Further prospective studies with larger sample sizes are warranted to confirm these findings.

Abbreviations

BMI Body Mass Index

ISI Insall-Salvati index

ROM range of motion

KBW Kirschner-wire tension band

KDL Krackow suturing combined with a double-loop tension-reducing

Declarations

Ethics approval and consent to participate

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Third Affiliated Hospital of Chongqing Medical University. Informed consent was obtained from all individual participants included in the study. The authors affirm that human research participants provided informed consent for the publication of the images.

Consent for publication

All patients included in this study provided written informed consent for the publication of their clinical information and any associated images. The patients were informed that their data would be published in an anonymized manner. All potentially identifying information has been appropriately removed or anonymized prior to publication. Written consent was obtained from each participant before submission of this manuscript.

Competing interests

The authors declare no competing interests.

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Author Contribution

All authors contributed to the study’s conception and design. Huilin Zhang and Feng Xie were responsible for the study design and development of the surgical protocol. Jinghua Xiang and Xiaoqiang He collected and processed the clinical data. Bozan Dong performed the statistical analysis. Huilin Zhang drafted the manuscript. Feng Xie critically reviewed and approved the final version of the manuscript.

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Data Availability

No datasets were generated or analysed during the current study.

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Figures

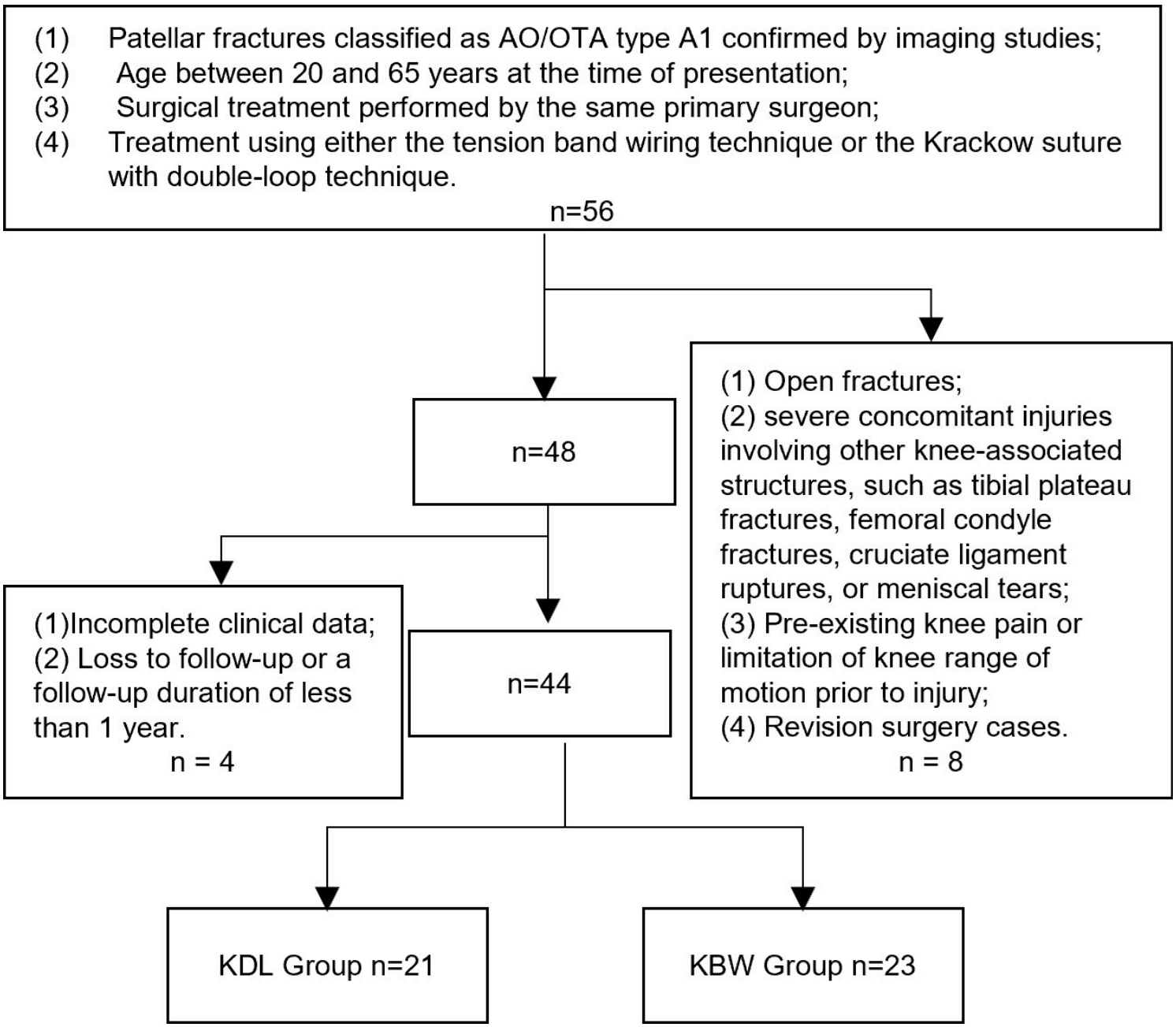


Figure 1

Flow chart of the study for patient inclusion. KDL technique: Krackow and double-loop technique; KBW technique: Kirschner-wire tension band technique.

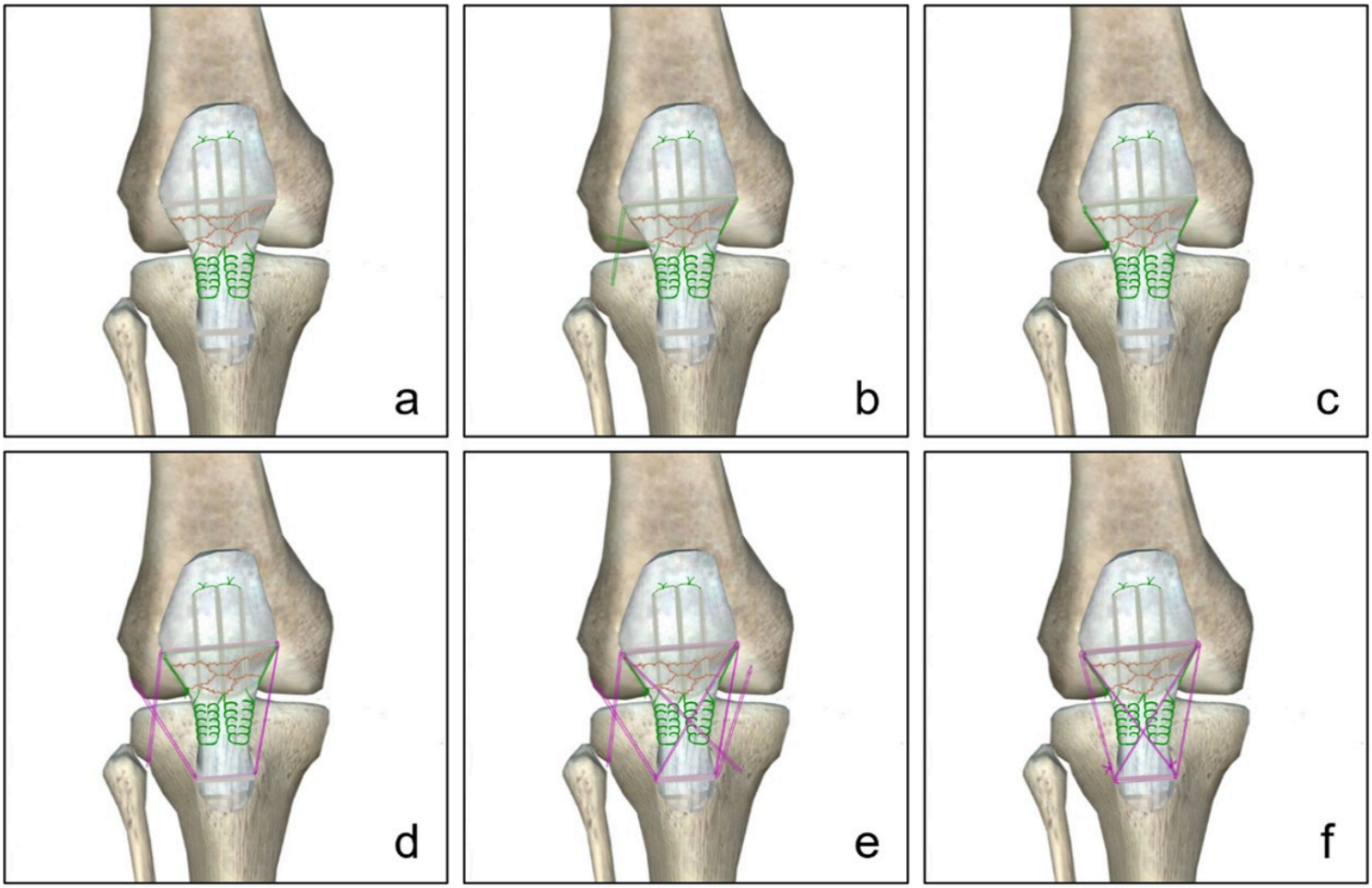


Figure 2

Krackow and double-loop (KDL) technique.
(a) Bone tunnel creation and Krackow suturing: Three parallel longitudinal patellar tunnels were created using a 2 mm Kirschner wire at the central, mediomedial one-third, and mediolateral one-third of the patella. A transverse patellar tunnel was drilled 1 cm proximal to the fracture line using a 3-mm Kirschner wire. A horizontal 2 mm tibial tunnel was created 1.5 cm posterior to the tibial tubercle. Krackow sutures were placed in the medial and lateral portions of the patellar ligament using No. 5 Ethibond sutures. The free ends of the sutures were sequentially passed through the distal patellar fracture fragment and the patellar bone tunnels, tightened with the knee flexed at 30°, and tied superior to the patella. **(b)** Distal patellar cerclage: A doubled No. 5 Ethibond suture was passed from the lateral outlet of the patellar tunnel to the medial outlet, looped around the inferomedial margin of the patella, passed beneath the inferior patellar surface through the patellar ligament, and exited along the lateral patellar cortex. **(c)** Completion of distal patellar cerclage with a Nice knot: With the knee maintained in hyperextension, the suture was tightened and secured with a Nice knot on the medial side of the patella. **(d)** Patella–

tibial tubercle “0”-shaped tension-reducing loop: A double-stranded 0# PDS suture was introduced through the lateral entry of the transverse patellar tunnel, exited medially, and passed clockwise through the tibial tunnel to form an “0”-shaped closed loop. **(e)** Patella–tibial tubercle “figure-of-eight” tension-reducing loop: A second double-stranded 0# PDS suture was introduced through the transverse patellar tunnel, exited medially, and passed counterclockwise through the tibial tunnel to form a figure-of-eight configuration. **(f)** Completion of patella–tibial cerclage: With the knee flexed at 30°, bilateral Nice knots were tied simultaneously to secure the patella–tibial cerclage.



Figure 3

Postoperative rehabilitation exercises. **(a)** Bedside dangling of the lower limb, suitable for knee flexion exercises ranging from 0° to 90°. **(b)** Wall-slide exercise, suitable for knee flexion exercises ranging from 90° to 110°. **(c)** Seated knee-hugging exercise, suitable for knee flexion exercises ranging from 100° to 120°. **(d)** Supine dangling of the lower limb, suitable for knee flexion exercises ranging from 100° to 130°.

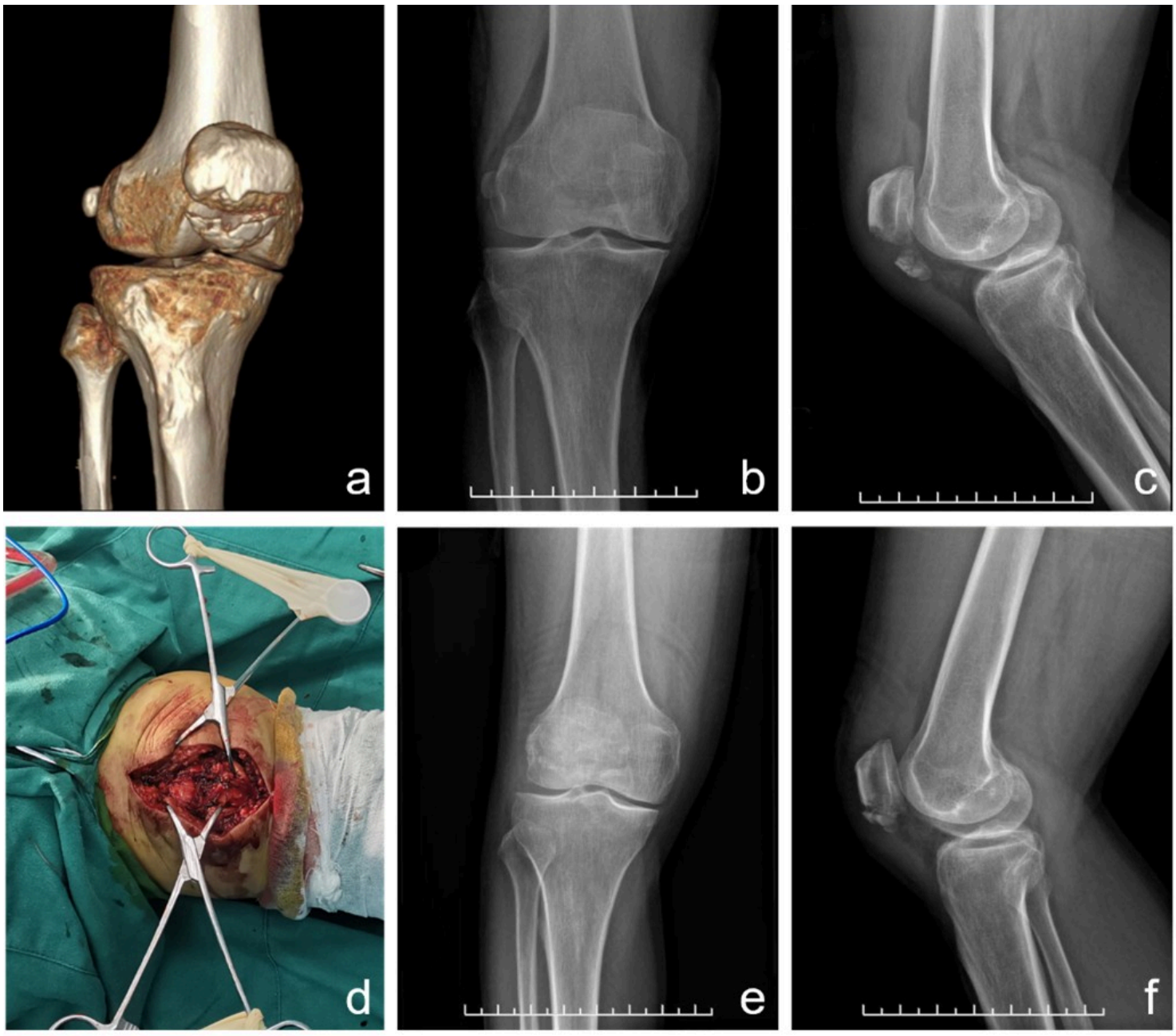


Figure 4

Case 1. A 64-year-old man sustained an inferior pole fracture of the right patella (AO classification: 34-A1) following a fall and was treated with the Krackow and double-loop (KDL) technique. **(a)**Preoperative computed tomography (CT) image. **(b)** Preoperative anteroposterior radiograph of the knee. **(c)** Preoperative lateral radiograph of the knee. **(d)** Intraoperative fixation of the inferior patellar fracture using Krackow suturing combined with distal patellar cerclage and patella–tibial cerclage. **(e)** Immediate postoperative anteroposterior radiograph of the knee. **(f)** Immediate postoperative lateral radiograph of the knee.

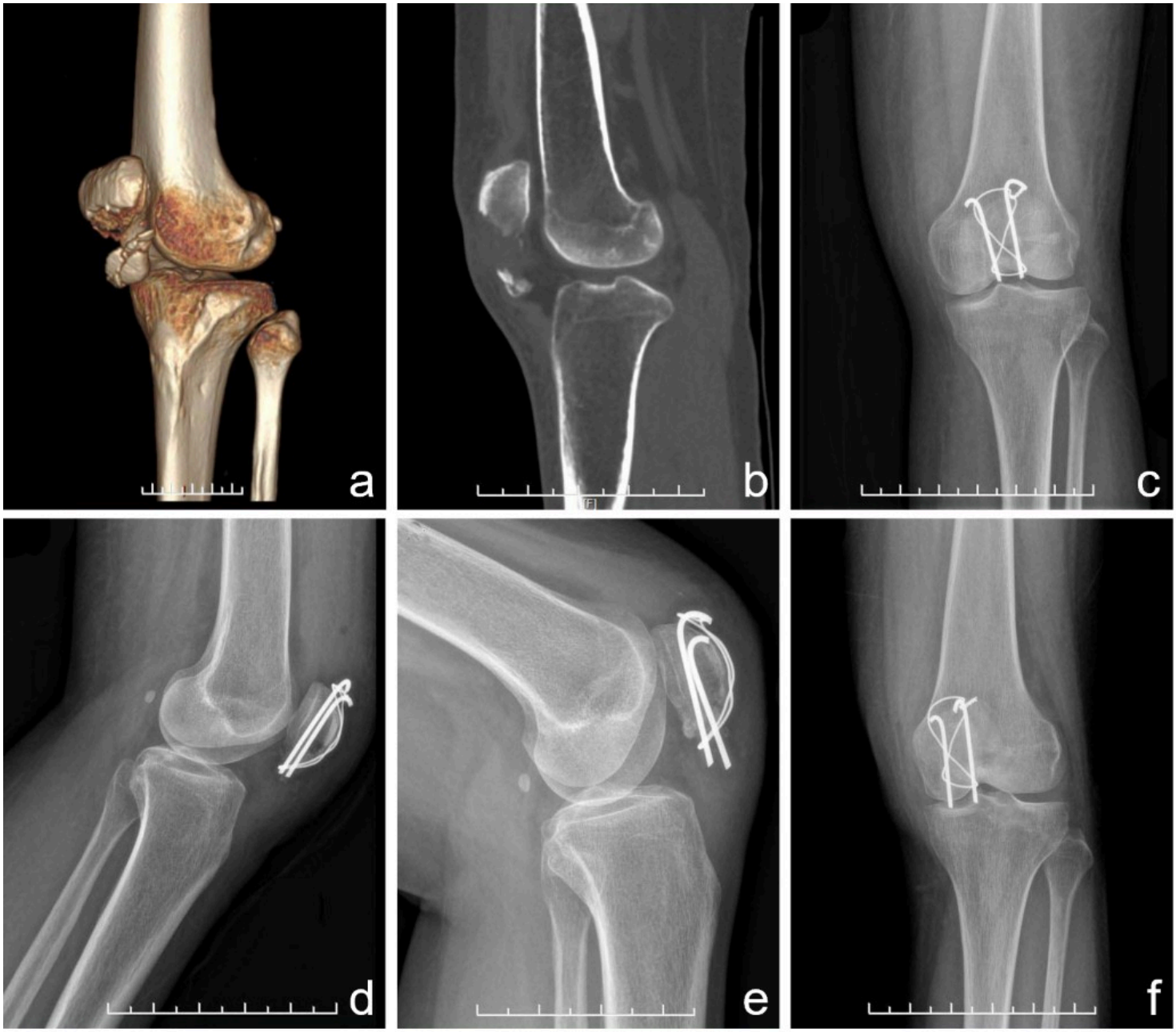


Figure 5

Case 2. A 55-year-old woman sustained an inferior pole fracture of the left patella (AO classification: 34-A1) following a bicycle-related fall and was treated with the Kirschner-wire tension band (KBW) technique. **(a)** Preoperative three-dimensional computed tomography (CT) reconstruction. **(b)** Preoperative sagittal CT image. **(c)** Immediate postoperative anteroposterior radiograph of the knee. **(d)** Immediate postoperative lateral radiograph of the knee. **(e)** Lateral radiograph of the knee at 2 months postoperatively demonstrating wire migration. **(f)** Anteroposterior radiograph of the knee at 2 months postoperatively demonstrating wire migration.