Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Targeted Stabilization of the Inferior Pole in Complex Patellar Fractures Using a low-profile Hooked Plate and cerclage

Hangyu Gu
Beijing Jishuitan Hospital
Cunxiang Ma
Beijing Jishuitan Hospital
Wei Han
Beijing Jishuitan Hospital
Weinan Zhang
Beijing Ai Kang Medical Co., Ltd.
Junqiang Wang
drwjq2026@sina.com
Beijing Jishuitan Hospital

Research Article

Keywords: Patellar fracture, Inferior pole, Plate fixation, 3D printing, Internal fixation, Clinical outcomes

Posted Date: November 5th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11320383/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Objective

To evaluate the early clinical outcomes of a low-profile hooked locking plate combined with cerclage for the treatment of complex patellar fractures, including comminuted and inferior pole fracture patterns.

Methods

This retrospective single-center study included 43 consecutive patients with complex patellar fractures treated between April 2024 and March 2025. All patients underwent open reduction and internal fixation using a patient-specific 3D-printed low-profile hooked locking plate. Outcomes assessed included fracture union, time to union, pain visual analogue score (VAS), range of motion, Böstman score, complications, and reoperations.

Results

Fracture union was achieved in 42 of 43 patients (97.7%), with a mean time to union of 8.48 ± 1.31 weeks. Functional outcomes were favorable, with a median Böstman score of 30 (IQR, 28–30), median range of motion of 135° (IQR, 130°–140°), and median VAS of 0 (IQR, 0–1). The overall complication rate was 11.6%, and the complication-related reoperation rate was 7.0%. No fixation failure of the inferior pole was observed.

Conclusion

The low-profile hooked locking plate combined with cerclage provided reliable fixation and favorable early outcomes in complex patellar fractures.

Background

Patellar fractures account for approximately 1% of all fractures in adults[1], and displaced fracture patterns are always managed by surgical treatment. However, the surgical treatment for patellar fracture are still challenging. Although anterior tension-band technique has been a mainstay of surgical technique for the patellar fracture, the result varies with reoperation rates of 0% to 60%[2, 3] and loss of reduction rate up to 22%[4]. In addition, not all patellar fracture patterns are suitable for tension band fixation, and the complexity of many patellar fractures is often underestimated by radiographs[5].

Given the limitations of conventional methods, novel plate and screw constructs have recently gained popularity and shown promising results[6–16]. However, no single implant design is suitable for all patellar fracture patterns, and fixation failure, particularly involving the inferior pole, remains a persistent

problem[17]. From many recent researches, inferior pole of patellar is commonly involved component in comminuted patellar fractures[18], and in a substantial proportion of cases the inferior pole itself is also comminuted[5, 19]. Despite the availability of various treatment methods, fixation failure at the inferior pole of the patella remains one of the most common complications following surgical treatment[17, 20]. In addition, a cadaveric study using magnetic resonance imaging demonstrated that the largest arteria contribution to the patella entered at the inferior pole in 100% of the specimens[21]. Given the paramount importance of the inferior pole of the patella in both mechanical stability and vascularity, the design of patellar plates and surgical strategies should aim to achieve mechanical stability while preserving the biological environment. Moreover, irritation caused by internal fixation should be minimized, which represents one of the major limitations of the Kirschner wire tension band technique[2].

In recent years, 3D-printed orthopedic implants have demonstrated promising results in fracture reduction and fixation[22–24]. A novel low-profile hook-shaped plate designed by the study team demonstrated favorable mechanical stability in finite element analysis[25]. This study aimed to evaluate the clinical outcomes of using a 3D-printed version of this plate for the treatment of complex patellar fractures.

Methods

Study design

This retrospective single-center study consecutively included 43 patients with complex patellar fractures treated in the Department of Orthopaedic Trauma between April 2024 and March 2025. Complex patellar fractures were defined as fractures involving comminution and/or the inferior pole.

Inclusion criteria

1. Acute unilateral patellar fractures (< 2 weeks) involving the inferior pole and/or comminuted patterns confirmed by X-ray and computed tomography (CT) (AO/OTA classification 34-A1 and 34-C2,3 fractures).

2. preoperative articular step >2 mm, or displacement > 2mm;

3. Treatment with open reduction and internal fixation using a 3D-printed low-profile anatomical hooked locking plate.

4. Postoperative follow-up of at least 6 months with complete clinical data.

Exclusion criteria

1. Multiple trauma or concomitant fractures affecting rehabilitation.

2. Open fractures, Old fractures (> 2 weeks), or pathological fractures.

3. Systemic diseases affecting bone metabolism or requiring long-term glucocorticoid use (e.g., rheumatoid arthritis, hyperparathyroidism).

4. Severe knee osteoarthritis (Kellgren–Lawrence grade ≥ III) or previous surgery on the affected knee (e.g., total knee arthroplasty or revision surgery).

5. Neurological disorders causing lower limb dysfunction (e.g., post-stroke hemiplegia, Parkinson's disease with Hoehn–Yahr stage ≥ III).

6. Patients with incomplete follow-up data.

Design and Manufacturing of the 3D-Printed Low-profile Patellar Plate

Preoperative computed tomography (CT) scans of both knees were obtained for three-dimensional reconstruction. The contralateral patella was used as the anatomical template for implant design. The acquired two-dimensional CT image series (DICOM format) were imported into Materialise's Interactive Medical Image Control System (MIMICS) for three-dimensional reconstruction. Subsequently, three-dimensional models of patella were reconstructed and distinguished using different colors (Figures 1A-B). The three-dimensional patellar model, along with the coronal, sagittal, and transverse reference planes defined in MIMICS, were exported in STL format and imported into Unigraphics NX (UG) software. Using CAD/CAM techniques, a hook-shaped low-profile locking plate was designed to conform to the anatomical morphology of the patella. The overall length of the plate and the width of the lateral wings were determined according to the morphology of the contralateral patella. Within the UG environment, an initial plate design sketch was created to determine the approximate position and dimensions of the plate on the patella, followed by construction of the three-dimensional plate model. Through CAD/CAM-based design, the anatomical plate achieved close conformity with the patellar bone surface (Figure 1C-D). In addition, the positions of the screw holes and trajectories were determined and simulated. The insertion direction of screws was optimized to align with the anatomical structure of the patella and to enhance mechanical stability (Figures 1E-F). After the plate design was completed, virtual simulation was performed to verify the anatomical fit and fixation feasibility. Following successful validation, the plate was fabricated using 3D printing technology (Figures 2A-C).

Surgical technique

Patients were placed in the supine position with a pneumatic tourniquet applied to the affected limb. A folded pad was placed beneath the ipsilateral hip and scapula to position the patella facing vertically upward. A longitudinal midline incision was made on anterior aspect of the knee, from the upper edge to lower edge of the patella. Full-thickness flaps deep at the fascial level were created, then hematoma and clots were evacuated. Inverted periosteum was excised to expose the anterior cortex near the fracture site, facilitating accurate evaluation of the quality of reduction.

Reduction followed the sequence of proximal to distal and deep (articular surface) to superficial layers. When coronal split fragments present as free articular or impacted types, the proximal fragment was

flipped proximally to expose the joint surface (Figure 3A-F), and the articular fragments were reduced and fixed by using 2.4 mm or 3.0 mm Herbert screws (DePuy Synthes, USA) (Figure 3G-H). Following reconstruction of the articular surface, the fracture was typically converted into a proximal patellar body and a distal inferior pole fragment. Following reduction of inferior pole fragment, circumferential fixation was achieved using either a high-strength suture or a titanium cable cerclage, selected based on intraoperative assessment and surgeon preference. After satisfactory reduction, the 3D-printed hook plate was inserted at the patellar tendon–bone junction. Fluoroscopy confirmed full contact between the hook portion and the inferior pole of the patella, then distal-to-proximal compression was applied. Special attention was paid to positioning the hook distal to the cerclage suture to prevent the hook from cutting through the distal fragment. Locking screws were then sequentially inserted to secure the plate and the retinaculum was repaired with absorbable sutures. Finally, the knee was cycled through a full range of motion. Both fluoroscopy and direct visualization with the knee in maximal flexion were used to confirm that the fracture fragments remained stable without micromotion before wound closure (Figure 3).

Post-operative rehabilitation

Rehabilitation is typically initiated on day 2 after the surgery. Protected full weight-bearing with crutches, isometric quadriceps-strengthening exercises, including seated exercises and straight leg raises were initiated under the guidance of a physical therapist. Knee flexion was progressively increased to 90° within the first 4 weeks. Full knee flexion comparable to the contralateral side was achieved by 8 weeks, at which point functional activities such as squatting and stair climbing were initiated. The entire rehabilitation process was conducted in the outpatient setting under close communication and supervision between the operating surgeon and the physiotherapist.

Follow-up

Patients were followed at 2, 4, 8, 12, 24, and 48 weeks postoperatively. At each follow-up visit, anteroposterior and lateral radiographs of the knee were obtained to assess implant position, fracture healing, joint stability, and functional recovery.

Clinical outcomes recorded included operative time, fracture healing time, pain intensity measured using the VAS, knee range of motion (ROM), Böstman score.

All data were collected and recorded by a trained research assistant who was blinded to the surgical details.

Results

A total of 43 patients were included, with a mean age of 56.6 ± 14.9 years (range, 17–83 years). There were 25 females (58.1%) and 18 males (41.9%). Inferior pole fractures accounted for 51.2% of cases, while 48.8% were comminuted fractures.

The median Böstman score was 30 (range, 18–30; IQR, 28–30). A total of 41 patients (95.3%) achieved an excellent score (≥ 28). The median VAS was 0 (range, 0–2; IQR, 0–1). Mild pain (VAS 1–2) was reported by 4 patients during strenuous activity or weather changes, but none required regular analgesic drugs (Fig. 4,5). The mean time to union was 8.48 ± 1.31 weeks (range, 8–12 weeks).

The overall complication rate was 11.6% (5/43). One patient developed multiple complications, including infection, implant-related irritation, and nonunion with loss of reduction of superior pole, while the other four patients presented with isolated implant-related irritation. Reoperation due to complications was required in three patients (7.0%). Several asymptomatic patients underwent implant removal at their own request despite the absence of clinical indications. These procedures were classified as elective and were not included in complication-related reoperation rate. (Table 1)

Table 1
Demographic characteristics and clinical outcomes of the patients

Variable	Value
Number of patients	43
Age (years)	56.6 ± 14.9
Sex (female/male)	25 / 18
Inferior pole fractures	22 (51.2%)
Comminuted fractures	21 (48.8%)
Fracture union	42/43 (97.7%)
Time to union (weeks)	8.48 ± 1.31
Böstman score	30 (IQR, 28–30)
Range of motion (°)	135 (IQR, 130–140)
VAS score	0 (IQR, 0–1)
Overall complication rate	5/43 (11.6%)
Complication-related reoperation rate	3/43 (7.0%)
Values are presented as mean ± standard deviation, median (interquartile range [IQR]), or number (%), as appropriate	

Discussion

The present study demonstrated that the 3D-printed low-profile anatomical hooked locking plate provides stable fixation for comminuted and inferior pole patellar fractures, with a union rate of 97.7% and a mean time to union of 8.48 ± 1.31 weeks. The overall complication rate was 11.6%, and the complication-related reoperation rate was 7.0%. Functional outcomes were favorable, with a median

Böstman score of 30 (IQR, 28–30) and a median VAS score of 0 (IQR, 0–1). Previous plate-based studies have demonstrated healing times generally ranging from 8 to 12 weeks, and complication rates between 10% and 30%[6–16, 20]. In this context, the present results fall within the upper range of reported outcomes with respect to fracture healing time, functional recovery, and implant-related irritation.

The management of patellar fractures, especially comminuted and inferior pole fractures, remains challenging. Although tension band wiring has long been considered the standard technique, its biomechanical principle of dynamic compression has been questioned, with evidence suggesting that it functions as a static rather than dynamic construct[26]. In addition, tension band fixation is associated with a relatively high incidence of complications, including fixation failure and implant-related irritation[2, 4, 27, 28]. Plate fixation has therefore gained increasing attention, with biomechanical studies demonstrating comparable or superior stability compared to tension band techniques[29–32]. However, most of these studies were based on idealized transverse fracture models, which do not fully replicate the complexity of comminuted or inferior pole fractures. Clinically, fixation failure at the inferior pole remains a persistent challenge[17]. Fixation of inferior pole represents a key determinant of stability in complex patellar fractures. The distal fragment is often small and comminuted[5, 19], and inferior pole involvement is common in multifragmentary patterns[18]. In addition, this region plays a critical role in the vascular supply of the patella[21]. Taken together, these factors highlight the importance of fixation strategies specifically targeting the inferior pole.

The implant and technique used in the present study were designed to address these challenges. First, the implant provides reliable mechanical stability, with the hook-shaped design significantly enhancing fragment capture and fixation strength at the inferior pole of the patella, which is often difficult to secure using conventional fixation methods[20]. In the present study, circumferential fixation using either high-strength sutures or titanium cable cerclage in combination with a hook-shaped plate provided multidirectional stabilization of the inferior pole in both the coronal and sagittal planes, effectively forming a “cage-like” construct that captures and supports the distal fragment. This configuration enhances fixation stability in small and comminuted fragments, and its biomechanical superiority over conventional tension band techniques has been demonstrated in finite element analyses[25]. Second, this technique minimizes dissection and disruption of the inferior pole of the patella. The distal fragment is often small and frequently comminuted, making it difficult to achieve stable fixation using screws alone[5, 19]. Attempts to secure screws within the inferior pole may further fragment the bone, cause secondary displacement, and lead to loss of bone stock. Moreover, the principal vascular supply to the patella is derived from vessels entering through the inferior pole[21]. Excessive dissection in this region may compromise blood supply and adversely affect fracture healing. In the present study, stability was achieved by capturing the tendon–bone junction rather than relying on direct fixation of the inferior pole fragment, thereby preserving bone stock while minimizing vascular disruption. Third, implant-related irritation was minimal in the present study. The low-profile design of the anatomical locking plate results in a thinner construct, with locking screws seated flush with the plate, thereby reducing hardware

prominence and minimizing soft-tissue irritation. Notably, the rate of implant-related irritation in the present study (11.6%) appears lower than that reported in some plate-based series, where rates of up to 28% have been described[10].

This study has several limitations. First, it is a single-center retrospective case series without a control group. Second, the sample size is limited and the follow-up duration is relatively short, precluding assessment of long-term outcomes such as patellofemoral osteoarthritis. Third, cost-effectiveness was not evaluated, and the expense associated with 3D-printed implants remains a potential limitation. Fourth, simple transverse fractures were not included, which may limit the generalizability of the findings. Finally, the potential impact of this technique on the vascularity of the inferior pole remains theoretical and warrants further investigation.

In summary, the present study highlights that successful management of complex patellar fractures depends not only on achieving anatomical reduction but also on effective stabilization of the inferior pole, which represents a key determinant of fixation stability. Unlike conventional fixation strategies that rely primarily on direct screw purchase in small and often comminuted fragments, the technique described in this study shifts the focus toward targeted stabilization of the inferior pole through a combination of hook engagement and circumferential fixation at the tendon–bone junction. This configuration functions as a cage-like construct, providing multidirectional support in both the coronal and sagittal planes while preserving bone stock and minimizing disruption to the vascular supply. Such an approach may help explain the absence of inferior pole fixation failure observed in this series. From a broader perspective, this strategy represents a conceptual shift from generalized fixation to problem-oriented fixation tailored to the most vulnerable component of the fracture, and may offer a valuable framework for future implant design and surgical planning in complex patellar fractures.

Conclusion

The low-profile anatomical locking plate combined with cerclage represents a reliable treatment option for complex patellar fractures. Its precise anatomical matching and stable fixation enable early rehabilitation and favorable clinical outcomes. This technique may represent a promising new direction in the design of patellar plate and surgical management of complex patellar fractures.

Abbreviations

CT: Computed tomography

IQR: Interquartile range

IRB: Institutional Review Board

ROM: Range of motion

VAS: Visual analogue scale

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the ethics of this study protocol was approved by the Institutional Review Board of Beijing Jishuitan Hospital (Approval No. 2020-15). Written informed consent was obtained from all individual participants (or their legal guardians) included in this study.

Consent for publication

Patients signed informed consent regarding publishing their data and photographs.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This work was supported by the Beijing Nova Program [Grant No. 20240484579]

Authors' contributions

HG: Conceptualization, methodology, investigation, writing—original draft, visualization. CM: Data curation, formal analysis, investigation. WH: Validation, resources, supervision. WZ: Software, data curation. JW: Conceptualization, project administration, supervision, writing—review and editing. All authors read and approved the final manuscript.

Acknowledgements

Not applicable.

References

1. Boström A. Fracture of the patella. A study of 422 patellar fractures. Acta Orthop Scand Suppl. 1972;143:1–80.
2. Greenberg A, Kadar A, Drexler M, Sharfman ZT, Chechik O, Steinberg EL et al. Functional outcomes after removal of hardware in patellar fracture: are we helping our patients? Archives of orthopaedic

and trauma surgery. 2018;138(3):325–30.
3. Dy CJ, Little MTM, Berkes MB, Ma Y, Roberts TR, Helfet DL, et al. Meta-analysis of re-operation, nonunion, and infection after open reduction and internal fixation of patella fractures. J trauma acute care Surg. 2012;73(4):928–32.
4. Smith ST, Cramer KE, Karges DE, Watson JT, Moed BR. Early complications in the operative treatment of patella fractures. J Orthop Trauma. 1997;11(3):183–7.
5. Lazaro LE, Wellman DS, Pardee NC, Gardner MJ, Toro JB, Macintyre NR, et al. Effect of computerized tomography on classification and treatment plan for patellar fractures. J Orthop Trauma. 2013;27(6):336–44.
6. Howatt J, Liew AS, Wilkin G. Patellar Fractures: Anatomy, Mechanics, and Surgical Management. J bone joint Surg Am volume. 2021;103(23):2237–46.
7. Hargett DI, Sanderson BR, Little MTM. Patella Fractures: Approach to Treatment. J Am Acad Orthop Surg. 2021;29(6):244–53.
8. Gu H, Zhu S, Li T, Wu X. Combination of Cable Cerclage and Hook Plate for the Fixation of Comminuted Fractures of Inferior Patellar Pole: A Review of 16 Consecutive Patients Followed Up for a Minimum of 1 Year. Orthop Surg. 2022;14(11):3111–8.
9. Cho J-W, Cho W-T, Sakong S, Choi W, Kang S, Bak P et al. Clinical and functional outcomes of fracture pattern-driven plate osteosynthesis technique for comminuted patellar fractures using multiple miniplates. Arch Orthop Trauma Surg. 2026;146(1).
10. Shymon SJ, Jansson H, Schneiderman BA, Nazareth A, Hoshino CM, Zinar DM, et al. Functional Outcomes of Patella Fractures Treated With Anterior Plate Osteosynthesis at One Year. J Orthop Trauma. 2021;35(1):e1–6.
11. Buschbeck S, Götz K, Klug A, Barzen S, Gramlich Y, Hoffmann R, Comminuted. AO-C3 fractures of the patella: good outcome using anatomically contoured locking plate fixation. Int Orthop. 2022;46(6):1395–403.
12. Kumar S, Mittal S, Manhas V, Sharma V. Functional and radiological outcomes following plating for displaced fractures of patella: A pilot study. Injury. 2022;53(2):691–7.
13. Raja BS, Jain A, Paul S, Choudhury AK, Kalia RB. Plate osteosynthesis in patellar fractures: a systematic review and meta-analysis. Eur J Orthop Surg traumatology: orthopedie traumatologie. 2022;32(8):1627–40.
14. Neumann-Langen MV, Sontheimer V, Näscher J, Izadpanah K, Schmal H, Kubosch EJ. Incidence of postoperative complications in patellar fractures related to different methods of osteosynthesis procedures - a retrospective cohort study. BMC Musculoskelet Disord. 2023;24(1):871.
15. Tsotsolis S, Ha J, Fernandes ARC, Park JY, Dewhurst M, Walker T, et al. To plate, or not to plate? A systematic review of functional outcomes and complications of plate fixation in patellar fractures. Eur J Orthop Surg traumatology: orthopedie traumatologie. 2023;33(8):3287–97.
16. Xie X, Zhu Y, Wang Y, Zhan Y, Eladio S-S, Luo C. Multi-planar fixation of displaced, multi-fragmentary patella fractures in elderly patients with anterior locking plates and cerclage wires: preliminary

results. Eur J Orthop Surg traumatology: orthopedie traumatologie. 2023;33(6):2253–60.

17. Hoskins W, Parola R, Gusho C, Bellamy JL, Bangura A, Rocca GJD, et al. High Failure Rates in Comminuted Patella Fractures (AO/OTA 34-C3) Fixed With an Isolated, New Patella-Specific 2.7-mm Variable-Angle Locking Plate. J Orthop Trauma. 2025;39(6):320–30.
18. Cho J-W, Yang Z, Lim EJ, Sakong S, Choi W, Son WS, et al. Multifragmentary patellar fracture has a distinct fracture pattern which makes coronal split, inferior pole, or satellite fragments. Sci Rep. 2021;11(1):22836.
19. Zhan Y, Zhang Y, Xie X, Luo C. Three-dimensional fracture mapping of multi-fragmentary patella fractures (AO/OTA 34C3). Annals translational Med. 2021;9(17):1364.
20. Chang C-H, Shih C-A, Kuan F-C, Hong C-K, Su W-R, Hsu K-L. Surgical treatment of inferior pole fractures of the patella: a systematic review. J experimental Orthop. 2023;10(1):58.
21. Lazaro LE, Wellman DS, Klinger CE, Dyke JP, Pardee NC, Sculco PK, et al. Quantitative and qualitative assessment of bone perfusion and arterial contributions in a patellar fracture model using gadolinium-enhanced magnetic resonance imaging: a cadaveric study. J bone joint Surg Am volume. 2013;95(19):e1401–7.
22. Ge Y, Xu C, Wang P. Clinical Application of 3D-Printed Patient-Specific Instruments in Nasal Bone Fracture Reduction: A Randomized Controlled Trial. J biomedical Mater Res Part B Appl biomaterials. 2025;113(9):e35655.
23. Jarayabhand R, Jiamton C, Puncreobutr C, Lohwongwatana B, Theerachai A, Fang C. Invited review article: Patient-specific 3D-Printed metal plates for osteotomy and fracture fixation: An illustrative series with workflow and regulatory considerations. J Orthop Surg. 2025;33(2):10225536251356724.
24. Choi JH, Lee JH, Lee SH, Jang WY. Clinical Efficacy of Three-Dimensional-Printed Pure Titanium Fracture Plates with Locking Screw Systems in Distal Tibia Fractures. Medicina (Kaunas, Lithuania). 2025;61(1).
25. Ma C, Pan J, Zhang T, Wang J, Han W, Gu H. A comparative finite element study of novel design hook plates for fixation of patella fracture. Injury. 2025;56(8):112567.
26. Zderic I, Stoffel K, Sommer C, Höntzsch D, Gueorguiev B. Biomechanical evaluation of the tension band wiring principle. A comparison between two different techniques for transverse patella fracture fixation. Injury. 2017;48(8):1749–57.
27. Miller MA, Liu W, Zurakowski D, Smith RM, Harris MB, Vrahas MS. Factors predicting failure of patella fixation. J trauma acute care Surg. 2012;72(4):1051–5.
28. Hoshino CM, Tran W, Tiberi JV, Black MH, Li BH, Gold SM, et al. Complications following tension-band fixation of patellar fractures with cannulated screws compared with Kirschner wires. J Bone Joint Surg Am. 2013;95(7):653–9.
29. Thelen S, Schneppendahl J, Baumgärtner R, Eichler C, Koebke J, Betsch M, et al. Cyclic long-term loading of a bilateral fixed-angle plate in comparison with tension band wiring with K-wires or

cannulated screws in transverse patella fractures. Knee surgery, sports traumatology, arthroscopy. official J ESSKA. 2013;21(2):311–7.

30. Karakasli A, Acar N, Ertem F, Ozmanevra R, Erduran M. A novel anatomical patellar plate for transverse patellar fracture - A biomechanical in-vitro study. Acta Orthop Traumatol Turc. 2017;51(4):337–41.
31. Dickens AJ, Salas C, Rise L, Murray-Krezan C, Taha MR, DeCoster TA, et al. Titanium mesh as a low-profile alternative for tension-band augmentation in patella fracture fixation: A biomechanical study. Injury. 2015;46(6):1001–6.
32. Banks KE, Ambrose CG, Wheeless JS, Tissue CM, Sen M. An alternative patellar fracture fixation: a biomechanical study. J Orthop Trauma. 2013;27(6):345–51.

Figures

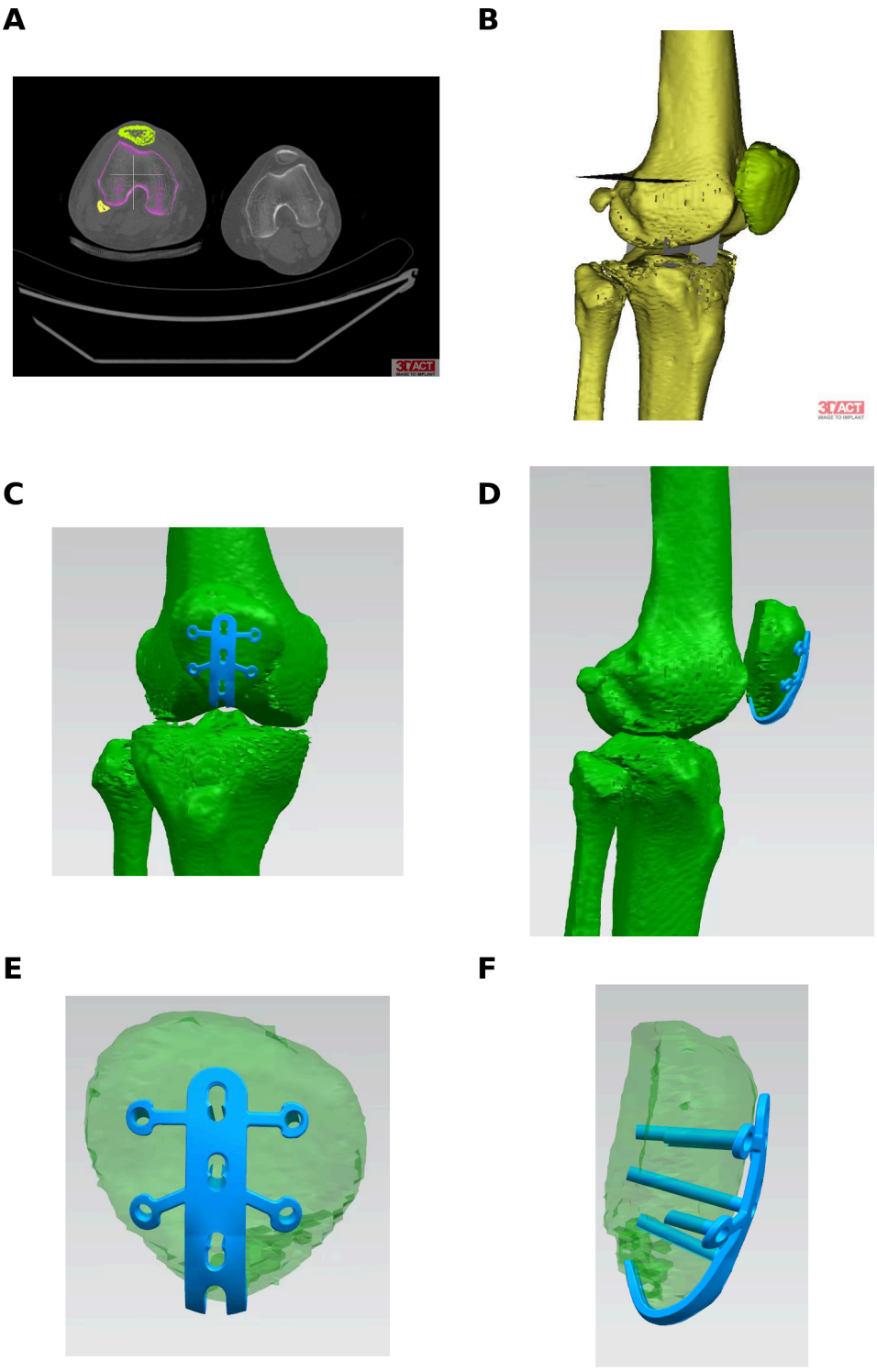


Figure 1

Workflow of patient-specific patellar plate design. (A) CT-based segmentation of the patella; (B) Three-dimensional reconstruction of the knee joint; (C) Planning of plate size and position; (D) Plate fitting on the patella; (E) Anterior view of the plate design; (F) Lateral view demonstrating plate conformity and screw trajectory.

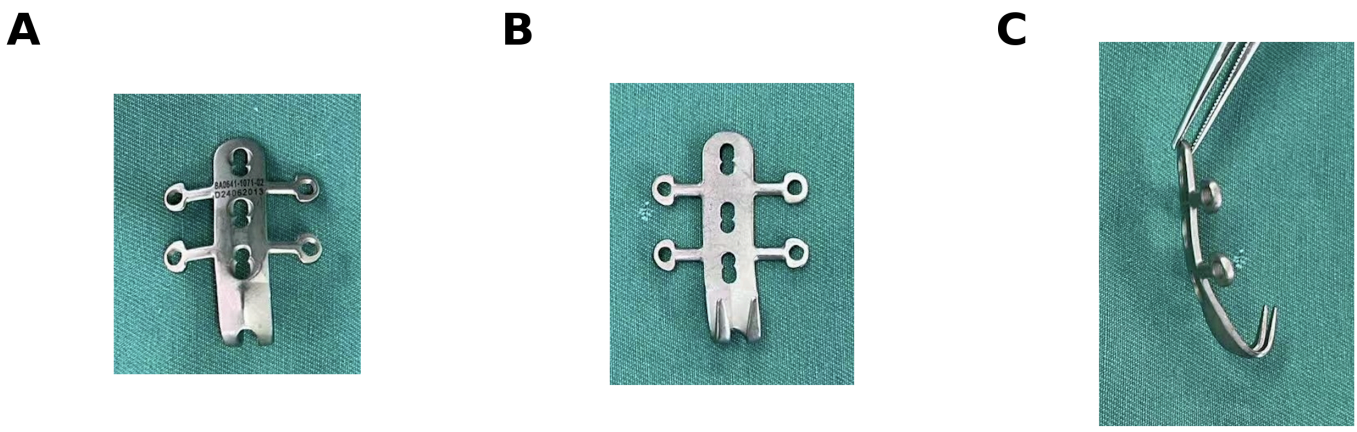


Figure 2

3D-printed anatomical hooked locking plate. (A) Anterior view demonstrating the configuration of screw holes and lateral wings. (B) Posterior view showing the plate contour designed to match the patellar surface. (C) Lateral view illustrating the low-profile curvature and distal hook for fixation of the inferior pole.

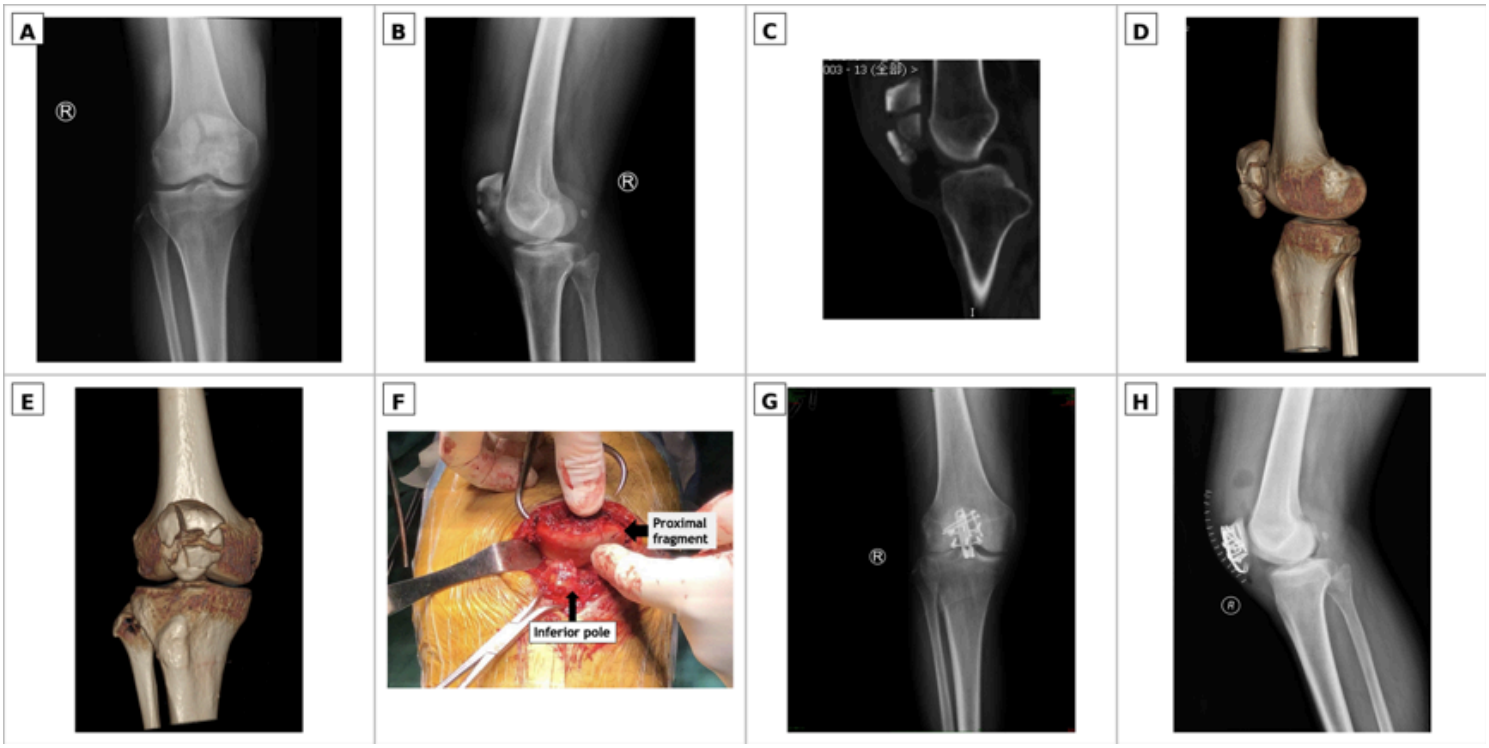


Figure 3

Stepwise surgical technique for fixation of comminuted patellar fractures with the inferior pole component. (A) Preoperative anteroposterior radiograph; (B) Preoperative lateral radiograph;

(C) Sagittal CT image demonstrating the free articular fragment and inferior pole fracture; (D–E) Three-dimensional CT reconstructions illustrating the comminuted fracture morphology; (F) Intraoperative exposure after flipping of the proximal fragment outwards, with direct visualization of the whole articular surface; (G-H) Reduction and fixation of articular fragments using headless compression screws, and final fixation using a 3D-printed hooked locking plate.

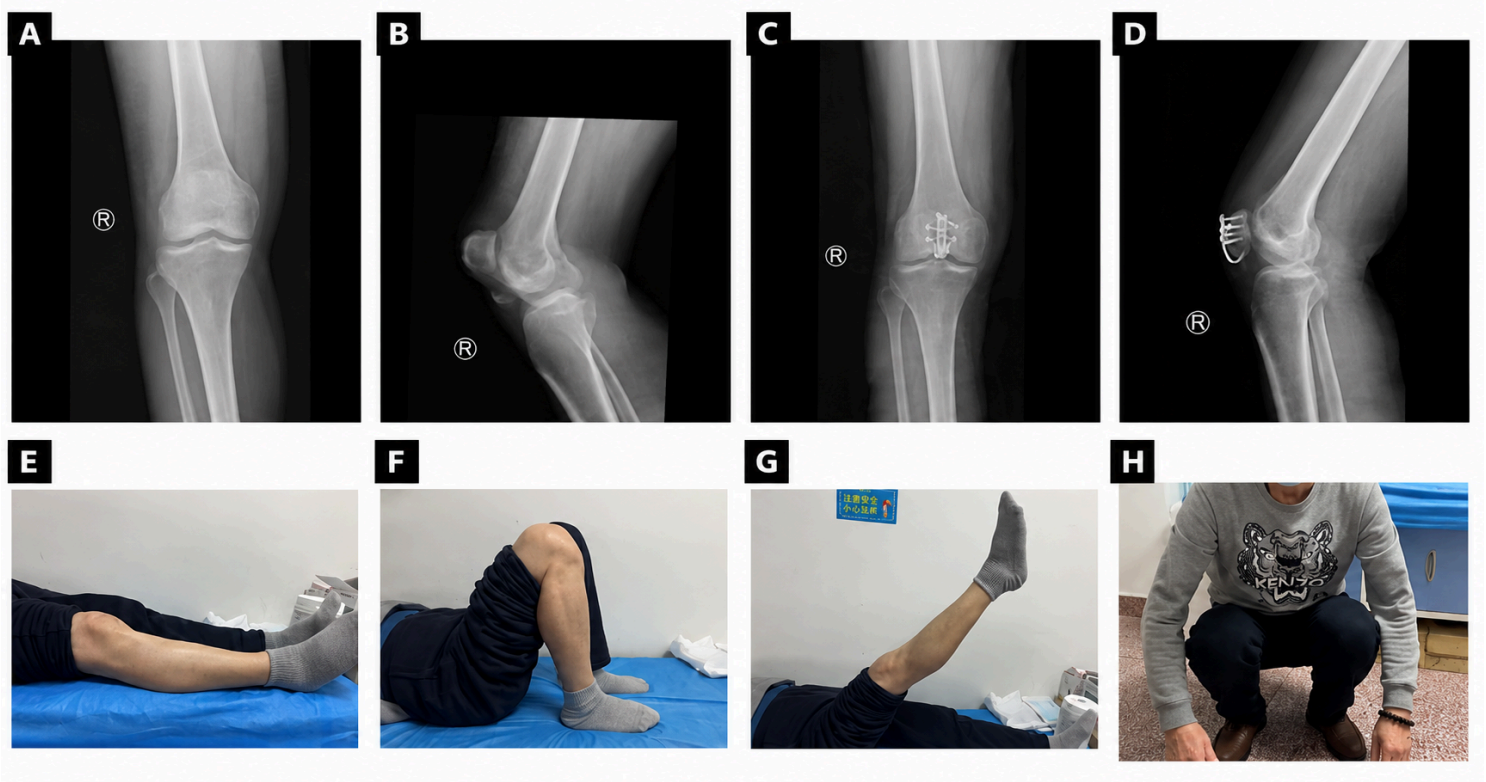


Figure 4

Case example 1: Male, 67 years old, acute right patellar fracture. (A, B) Preoperative anteroposterior and lateral radiographs. (C, D) Anteroposterior and lateral radiographs at 12 weeks postoperatively demonstrating satisfactory fracture healing. (E, F) Clinical evaluation showing full knee extension and flexion. (G, H) Straight leg raise and squatting, demonstrating good quadriceps function.

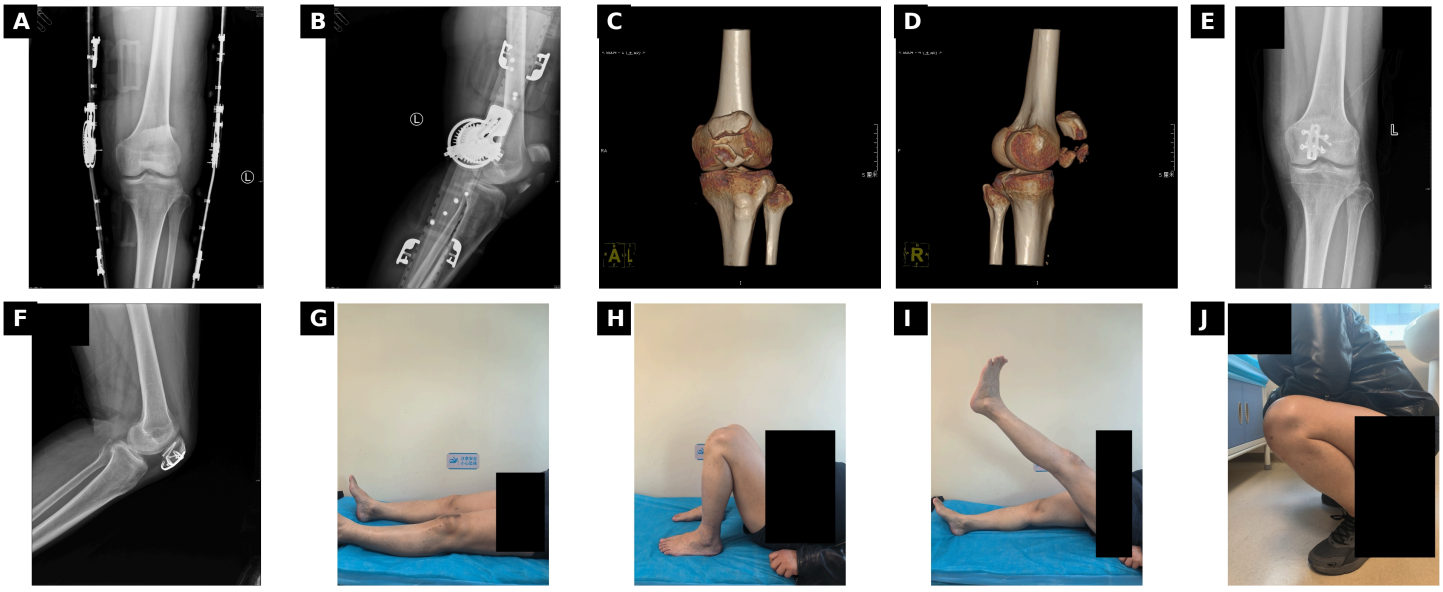


Figure 5

case example 2: Male, 58 years old, acute left patellar fracture. (A-D) Preoperative X-ray and 3D reconstruction of CT scan of the left knee, showing comminuted patellar fracture with the components of free articular fragments and inferior pole. (E, F) Twelve-week postoperative anteroposterior and lateral radiographs showing solid fracture union with anatomical reduction of articular surface and inferior pole. (G, H) Clinical photographs demonstrating full, unrestricted left knee extension and flexion. (I, J) Functional evaluation showing straight leg raise and deep squat, indicating satisfactory quadriceps strength.