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Comparison of the treatment of patellar inferior pole fractures with combined vertical wire and mini steel plate fixation versus independent vertical wire fixation

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A B S T R A C T

Background: Patellar fractures, in particular inferior pole fractures, pose significant challenges due to the patella's complex biomechanics and crucial role in knee extension and stability. This study aimed to compare the therapeutic effectiveness and long-term efficacy of two fixation methods: combined vertical wire and mini steel plate fixation versus independent vertical wire fixation. The comparison was based on clinical classification, addressing the ongoing debate regarding optimal management strategies for patellar inferior pole fractures.

Methods: A retrospective cohort study was conducted, analyzing 226 patients with patellar inferior pole fractures. Patients were divided into two groups: the independent vertical wire fixation group (n = 117) and the combined vertical wire and mini steel plate fixation group (n = 109). Demographic data, clinical characteristics, surgical outcomes, functional outcomes, pain levels, return to daily activities, quality of life, and both short-term and long-term complications were assessed and compared between the two groups.

Results: The combined fixation group demonstrated significantly superior surgical outcomes, including shorter operation times and lower infection rates, despite higher blood loss. Furthermore, this group exhibited enhanced functional outcomes, reduced pain levels, and lower rates of osteoarthritis and salvage procedures compared with the independent fixation group.

Conclusions: The findings of this study suggest potential advantages of combined vertical wire and mini steel plate fixation over independent vertical wire fixation in the treatment of patellar inferior pole fractures. The combined fixation method was associated with improved surgical outcomes, enhanced functional recovery, better pain management, and reduced long-term complication rates.

1. Introduction

Patellar fractures constitute approximately 1% of all skeletal fractures, representing a significant orthopedic concern. The patella plays a crucial role in the knee's extensor mechanism and is susceptible to fractures due to direct trauma or indirect forces, such as strong quadriceps contraction against a flexed knee [1–3]. These fractures present a considerable challenge

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due to the complex biomechanics and the patella's functional importance in knee extension and stability. Consequently, determining the most effective treatment approach for patellar fractures, in particular inferior pole fractures, is of paramount importance. The optimal management of patellar inferior pole fractures remains a subject of ongoing debate, with various surgical techniques and fixation methods being employed to address these complex injuries [4,5]. Internal fixation has been widely utilized as a common approach to stabilize these fractures and promote postoperative functional recovery. The primary objectives of internal fixation techniques are to provide mechanical stability to the fractured patella, facilitate appropriate healing, and enable early mobilization and rehabilitation to enhance functional recovery [6–8]. These techniques involve the implementation of implants, such as wires, plates, or screws, to stabilize the fracture fragments and restore knee joint integrity.

Two widely employed internal fixation methods for patellar inferior pole fractures are independent vertical wire fixation and combined vertical wire and mini steel plate fixation [9–11]. While both techniques have demonstrated efficacy in providing mechanical stability and promoting fracture healing, the comparative therapeutic effectiveness and long-term outcomes of these approaches remain to be fully elucidated.

This study aimed to compare the therapeutic effectiveness and long-term efficacy of combined vertical wire and mini steel plate fixation versus independent vertical wire fixation for the treatment of patellar inferior pole fractures. The comparison was based on clinical classification.

2. Materials & methods

2.1. Study population

The study population comprised patients diagnosed with patellar inferior pole fractures who were admitted to our institution from January 2023 to December 2023. This retrospective cohort study analyzed the clinical data of these patients. Based on the internal fixation methods employed, the patients were stratified into two groups: the independent vertical wire fixation group (n = 117) and the combined vertical wire and mini steel plate fixation group (n = 109).

2.2. Inclusion and exclusion criteria

Inclusion criteria were as follows: (1) initial radiographic evaluation, including X-ray and computed tomography scans, confirming comminuted inferior patellar pole fractures, classified as type 34 A1 according to the AO/OTA classification system; (2) clinical examination demonstrating functional impairment of the knee extension mechanism attributable to the patellar fracture; (3) closed, acute fractures with an interval between injury and surgical intervention not exceeding three weeks; (4) patients aged 18 years or older; (5) no prior history of patellar fractures.

Exclusion criteria were as follows: (1) pre-existing ambulatory difficulties or functional limitations antecedent to the current injury; (2) incomplete or inadequate clinical data; (3) concomitant fractures at other anatomical sites resulting from the same traumatic event; (4) follow up duration less than 12 months post-intervention; (5) pre-existing medical conditions known to impair fracture healing, including metabolic disorders and neurodegenerative diseases such as Alzheimer's disease.

2.3. Operative technique

2.3.1. Independent vertical wire fixation group

Spinal or combined spinal-epidural anesthesia was administered, with the patient positioned supine. A transverse arch-shaped incision was made at the inferior patellar pole, followed by layer-by-layer dissection to expose the torn patellar ligament, damaged patella ligament, and fractured patellar fragments. The proximal fracture fragments were anatomically reduced and temporarily fixed using pointed reduction forceps. Subsequently, two to three stainless steel wires (Ø 1.0 mm) were utilized for independent vertical fixation (Figure 1(a), (b)). The surgical outcome was assessed through full range of motion testing of the knee joint. Following hemostasis and normal saline irrigation, a subcutaneous negative pressure drainage tube was placed anterior to the patella. The wound was closed in layers after confirming proper instrument placement. Sterile dressings were applied, the tourniquet was released, and the patient was transferred to the ward. Post-fracture healing, all patients, except those of advanced age or poor physical condition, underwent wire removal at the hospital.

2.3.2. Combined vertical wire and mini steel plate fixation group

Lumbar puncture anesthesia was administered to all patients. Following satisfactory anesthesia, patients were positioned supine. An inflatable tourniquet (pressure set at 60 kPa) was applied to the elevated and flexed limb after routine disinfection and draping. A midline longitudinal incision was made anteriorly on the patella, exposing the fractured patellar pole end. Inverted periosteal tissue at the fracture edge was excised, and blood clots and intra-articular hematoma were debrided. A bone tunnel was created at the proximal fracture edge using a Kirschner wire, through which four wires were inserted retrogradely. A seven-hole 2.0-mm mini steel plate (LCP Compact Hand, DePuy Synthes, USA; Figure 2) was contoured

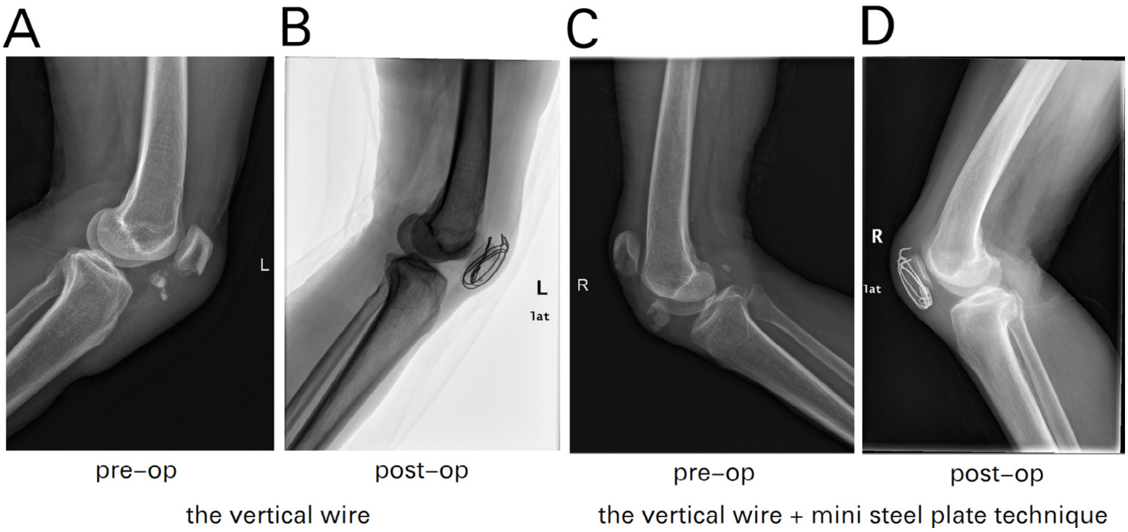

Figure 1. Radiographic comparison of vertical wire alone technique and vertical wire with mini steel plate technique for patellar inferior pole fractures. (a) Pre-operative radiograph of independent vertical wire fixation. (b) Postoperative radiograph of independent vertical wire fixation. (c) Pre-operative radiograph of combined vertical wire and mini steel plate fixation. (d) Postoperative radiograph of combined vertical wire and mini steel plate fixation.

and inserted posterior to the patellar tendon at the distal fractured patellar pole, closely following the patellar edge. Two sets of wires on each side passed through the plate holes, while the middle two wires passed around the plate posteroanteriorly, reducing the fractured end. The four wires were sequentially tightened and knotted to compress the fracture. Satisfactory reduction and fixation were confirmed by fluoroscopy with a 'C'-arm X-ray machine, demonstrating stable fracture ends during passive knee flexion and extension to approximately 130° (Figure 1(c), (d)). Following hemostasis and normal saline irrigation, a subcutaneous negative pressure drainage tube was placed anterior to the patella. The wound was closed in layers after confirming proper instrument placement. Sterile dressings were applied, the tourniquet was released, and the patient was transferred to the ward. Post-fracture healing, all patients, except those of advanced age or poor health, underwent steel wire and plate removal at the hospital.

2.4. Data Collection

A comprehensive compilation of patients' demographic and clinical characteristics was undertaken. Demographic data encompassed age, gender, and presence of comorbidities such as hypertension and diabetes. Clinical features were documented, including the presence of osteoporosis, utilization of non-steroidal anti-inflammatory drugs (NSAIDs) and bisphosphonates, and the interval between injury and surgical intervention. Additional demographic information was recorded, comprising the affected side, mechanism of injury, and history of previous knee joint surgeries. Baseline characteristics pertaining to the patients and their condition were collected. These included pre-operative knee range of motion, pre-operative knee joint social scores, pre-operative visual analog scale (VAS) scores, and pre-operative knee joint functional assessments. Surgical outcomes and associated complications were meticulously documented. The duration of the surgical procedure, intra-operative blood loss, and infection rates were recorded. Postoperative functional outcomes were assessed, including knee range of motion, knee joint functional assessments, and Kujala scores. The degree of postoperative pain experienced by patients was also captured. The patients' return to daily activities was monitored, with specific attention to the duration of partial weight-bearing, full weight-bearing, and resumption of previous activities. Quality of life scores were evaluated, and any complications or adverse events were recorded. These included nerve injuries, implant-related complications, postoperative arthritis, wound dehiscence, hardware irritation, and other relevant complications. Long-term complications and reoperation rates were documented, encompassing the incidence of osteoarthritis, chronic pain, implant removal, joint stiffness, and any necessary salvage surgeries.

2.5. Knee range of motion assessment

The flexion–extension measurement technique was employed to evaluate knee joint flexibility and injury status. During the assessment, patients were seated with their legs suspended. The maximum flexion angle was recorded as patients slowly flexed and extended their knees.

Figure 2. The seven-hole 2.0-mm mini steel plate.

2.6. Knee society score

The Knee Society Score (KSS) comprehensively evaluates pain, range of motion, and anterior–posterior and medial–lateral stability. Deductions are made for flexion contracture, extension lag, and alignment. The total score is 100 points, with classifications as follows: 85–100 (excellent), 70–84 (good), 60–69 (fair), and < 60 (poor). Higher scores indicate superior knee joint function. The pre-operative KSS reliability ranges from 0.83 to 0.92 [12].

2.7. VAS

Patient pain levels were quantified using the VAS, a numerical scale from 0 to 10. The scale is interpreted as follows: 0 (no pain), 1–3 (mild, tolerable pain), 4–6 (moderate pain, potentially disrupting sleep but manageable), and 7–10 (severe or intense pain, significantly impacting sleep quality and appetite). Higher VAS scores correspond to more intense pain. The VAS score reliability is reported as 0.94 [13].

2.8. Lysholm score

The Lysholm Score is a widely utilized clinical and research tool for evaluating knee joint function and rehabilitation efficacy. This assessment comprises eight domains: pain, swelling, giving way, locking, limp, support, activities of daily living, and recreational activities. Each domain is assigned a specific score, with a maximum total of 100 points. Pain and swelling are weighted more heavily, with 25 and 20 points, respectively, while other domains carry lower scores. Higher total scores indicate superior knee joint function and more favorable rehabilitation outcomes. The reported reliability of this scale is 0.71 [14].

2.9. Kujala score

The Kujala Knee Score is a prevalent scale for assessing knee joint function and symptoms. This assessment consists of 13 multiple-choice questions addressing activity limitations, pain, and joint instability. Each item is differentially scored to reflect the patient's specific condition. The total score is 100 points, with higher scores indicating better knee joint function. The reported reliability of this scale is 0.806 [15].

2.10. Quality of life assessment

The Short Form 36 scale (SF-36) was employed to assess health-related quality of life. This widely utilized instrument evaluates various aspects of health status across diverse populations, encompassing physical functioning, mental health, social functioning, and overall well-being. The SF-36, a comprehensive health assessment tool, comprises eight health-related quality of life domains. These domains address physical functioning, role limitations due to physical health, emotional problems, energy/fatigue, emotional well-being, social functioning, pain, and general health perceptions. Each question is scored on a five-point Likert scale ranging from 'excellent' to 'poor'. Scores for individual questions range from 0 to 100, with higher scores indicating less impact from the corresponding issue. The reliability coefficients for this scale range from 0.753 to 0.933 [16].

2.11. Statistical methods

Statistical analysis of pre-operative, intra-operative, and follow up data was conducted using SPSS 29.0 software (SPSS Inc., Chicago, IL, USA). Categorical variables were presented as n (%). Continuous variables were reported as

Table 1
Demographic and clinical characteristics of patients.

Parameter	Combined vertical wire and mini steel plate fixation	Independent vertical wire fixation	t/χ^2	P
Age (years)	45.12 ± 8.76	46.55 ± 7.92	1.286	0.2
Gender (M/F)	65 (55.56%)/52 (44.44%)	55 (50.46%)/54 (49.54%)	0.402	0.526
BMI (kg/m^2)	25.18 ± 2.14	24.96 ± 1.92	0.801	0.424
Smoking history (%)	15 (12.82%)	18 (16.51%)	0.357	0.55
Drinking history (%)	17 (14.53%)	21 (19.27%)	0.598	0.439
Hypertension (yes/no)	18 (15.38%)/99 (84.62%)	20 (18.35%)/89 (81.65%)	0.174	0.676
Diabetes (yes/no)	10 (8.55%)/107 (91.45%)	11 (10.09%)/98 (89.91%)	0.029	0.865
Osteoporosis (yes/no)	8 (6.84%)/109 (93.16%)	10 (9.17%)/99 (90.83%)	0.162	0.687
NSAID use (yes/no)	45 (38.46%)/72 (61.54%)	46 (42.2%)/63 (57.8%)	0.191	0.662
Bisphosphonate use (yes/no)	5 (4.27%)/112 (95.73%)	6 (5.5%)/103 (94.5%)	0.015	0.904
Time from injury to surgery (days)	5.32 ± 1.42	5.65 ± 1.68	1.626	0.105

BMI, body mass index; NSAID, non-steroidal anti-inflammatory drug.

mean ± standard deviation. The Shapiro–Wilk test was utilized to assess normality of distribution. Group comparisons were performed using independent-samples *t*-tests, while pre- and postoperative values were compared using paired-samples *t*-tests. Statistical significance was established at $P < 0.05$.

2.12. Ethical approval

This study was approved by the Ethics Committee of Dongyang People's Hospital (DY-2023-018).

Table 2
Additional demographic features.

Parameter	Combined vertical wire and mini steel plate fixation (n = 117)	Independent vertical wire fixation (n = 109)	χ^2	*P*
Side of fracture (right/left)	54 (46.15%)/63 (53.85%)	55 (50.46%)/54 (49.54%)	0.264	0.607
Mechanism of injury			2.854	0.24
Sports-related	35 (29.91%)	44 (40.37%)		
Trauma	70 (59.83%)	54 (49.54%)		
Other	12 (10.26%)	11 (10.09%)		
Previous knee surgery (yes/no)	15 (12.82%)/102 (87.18%)	16 (14.68%)/93 (85.32%)	0.045	0.832

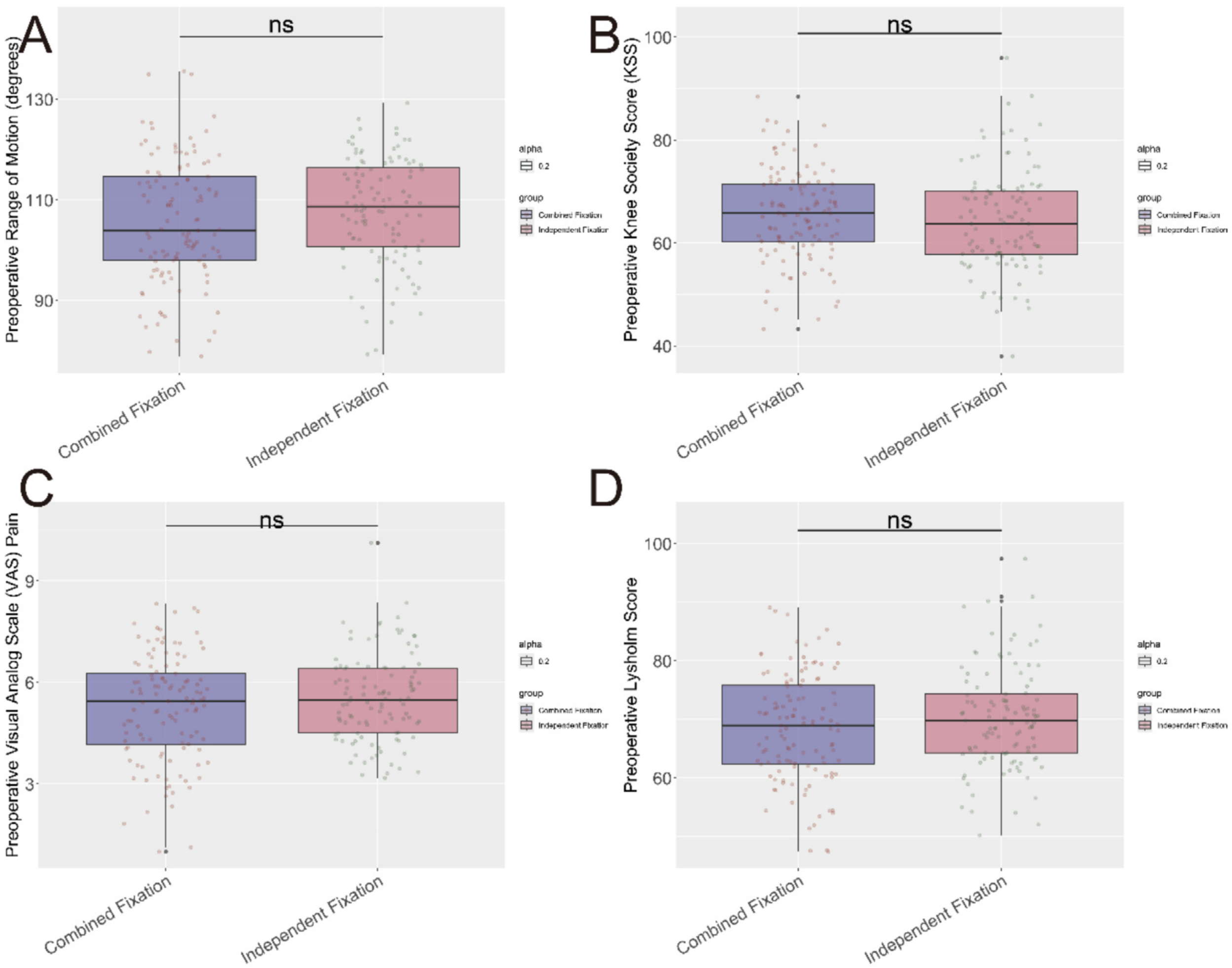

Figure 3. Baseline disease-related features. ns,???

3. Results

3.1. Demographic and clinical characteristics

The study evaluated the therapeutic effectiveness and long-term efficacy of two treatment modalities for patellar inferior pole fractures: combined vertical wire and mini steel plate fixation versus independent vertical wire fixation. The evaluation was based on clinical classification (Table 1). Demographic and clinical characteristics of patients receiving the two treatment modalities were comparable, with no statistically significant differences observed in key parameters. These parameters included age, gender distribution, body mass index (BMI), smoking and drinking history, presence of hypertension, diabetes, osteoporosis, use of NSAIDs and bisphosphonates, as well as the time interval from injury to surgical intervention ($P > 0.05$). The absence of significant differences in these baseline characteristics demonstrates the comparability of the two patient groups at the study's outset. This comparability enhances the validity of subsequent comparisons between the two treatment modalities.

3.2. Additional demographic features

Statistical analysis revealed no significant differences between the two treatment groups regarding fracture side, injury mechanism (categorized as sports-related, trauma-related, or other causes), and history of previous knee surgery ($P > 0.05$) (Table 2). These findings indicate comparable additional demographic characteristics between the groups, thereby enhancing the validity of inter-group comparisons conducted in this study.

3.3. Baseline disease-related features

Comparative analysis of the combined vertical wire and mini steel plate fixation group versus the independent vertical wire fixation group demonstrated no statistically significant differences in pre-operative parameters. These parameters included range of motion, KSS, VAS pain scores, and Lysholm Score ($P > 0.05$) (Figure 3). The absence of substantial differences in these baseline disease-related factors underscores the comparability of initial clinical characteristics and disease severity between the two groups at the study's commencement.

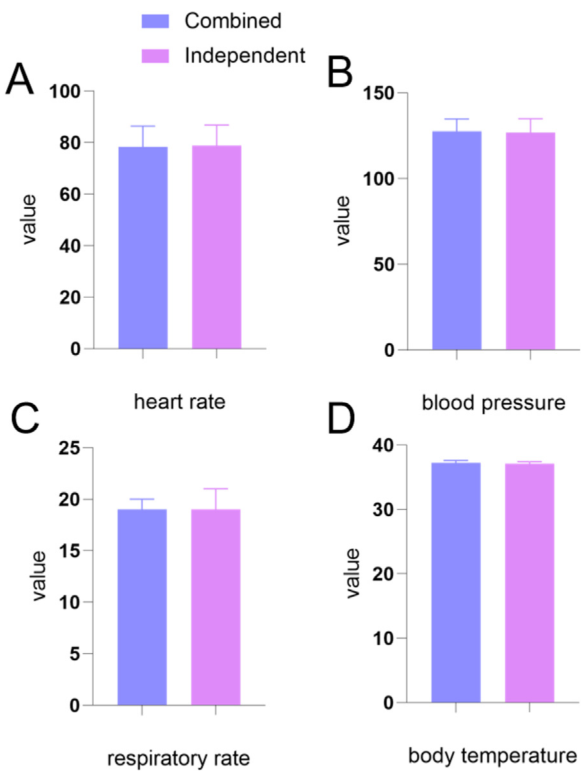

Figure 4. The physiological indicators after surgery.

3.4. Surgical outcome and complications

Post-surgical physiological indicators remained stable in both patient groups. No significant differences were observed in heart rate (78.35 ± 8.12 vs. 78.87 ± 7.98, $P > 0.05$), blood pressure (127.50 ± 7.36 vs. 126.79 ± 8.10, $P > 0.05$), respiratory rate (19 ± 1 vs. 19 ± 2, $P > 0.05$), or body temperature (37.2 ± 0.4 vs. 37.1 ± 0.3, $P > 0.05$) (Figures 4–6). However, statistically significant differences were identified in several surgical parameters. Operation time: 74.74 ± 12.45 vs. 78.45 ± 14.21 min ($t = 2.078$, $P = 0.039$). Blood loss: 124.67 ± 32.21 vs. 113.49 ± 32.75 ml ($t = 2.586$, $P = 0.01$). Infection rate: 1.71% vs. 8.26% ($\chi^2 = 3.906$, $P = 0.048$). These results suggest that the combined vertical wire and mini steel plate fixation technique was associated with shorter operation times, increased blood loss, and a lower infection rate compared with independent vertical wire fixation. These findings indicate potential differences in surgical outcomes and postoperative complications between the two techniques (Table 3).

3.5. Functional outcomes

Statistical analysis revealed significant differences in several functional parameters between the two treatment groups. Knee range of motion: 126.96 ± 8.92 vs. 123.58 ± 9.37° ($t = 2.779$, $P = 0.006$); Lysholm score: 87.02 ± 6.72 vs. 84.76 ± 7.91 ($t = 2.308$, $P = 0.022$); Kujala score: 79.15 ± 7.58 vs. 76.69 ± 8.23 ($t = 2.332$, $P = 0.021$) (Figure 7). These findings indicate that patients who underwent combined vertical wire and mini steel plate fixation demonstrated superior functional outcomes compared with those treated with independent vertical wire fixation. The observed differences suggest potential variations in postoperative functional recovery between the two surgical techniques.

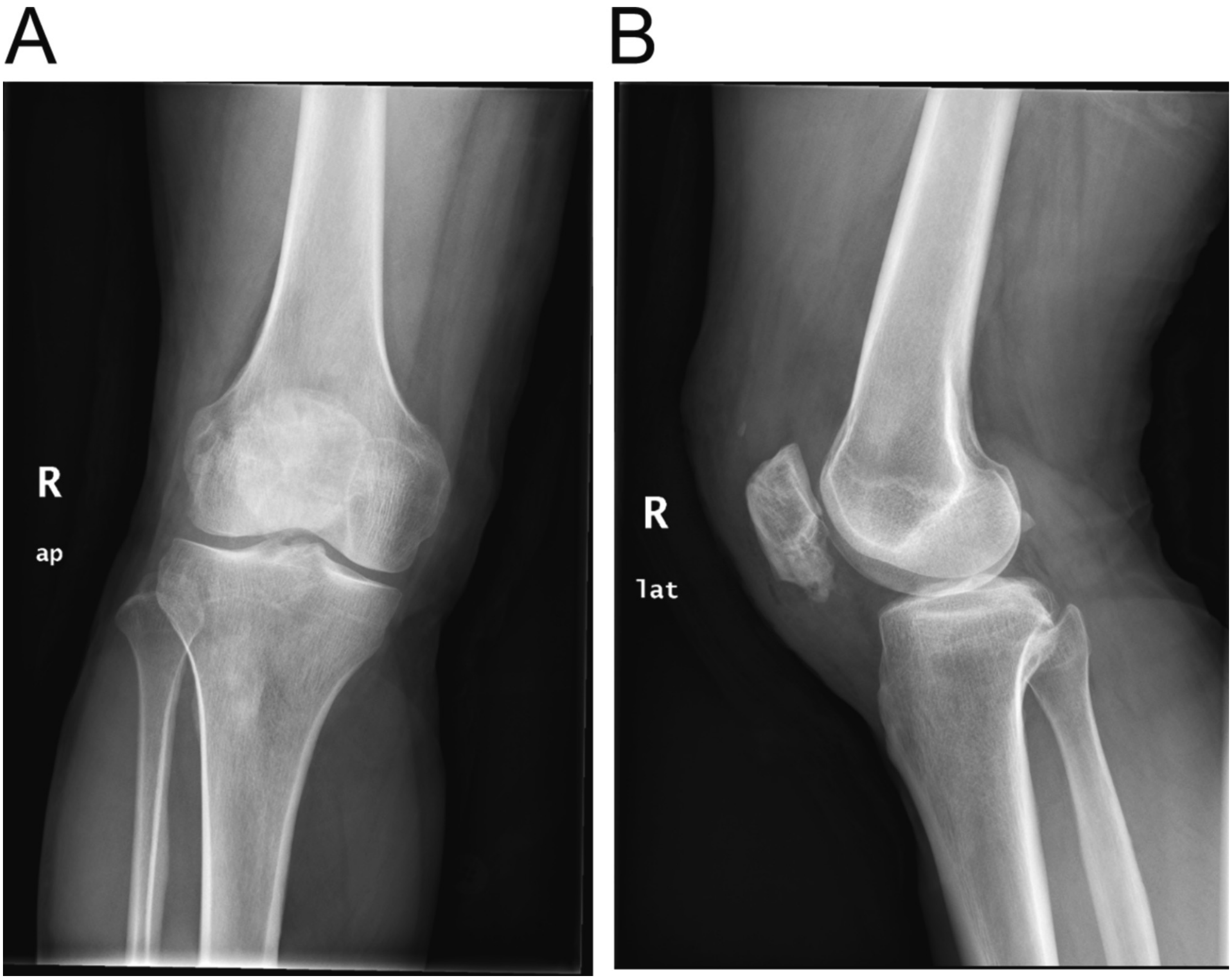

Figure 5. Anteriorposterior views with steel wire and plate removed during postoperative rehabilitation. (a) Anteposition; (b) side position.

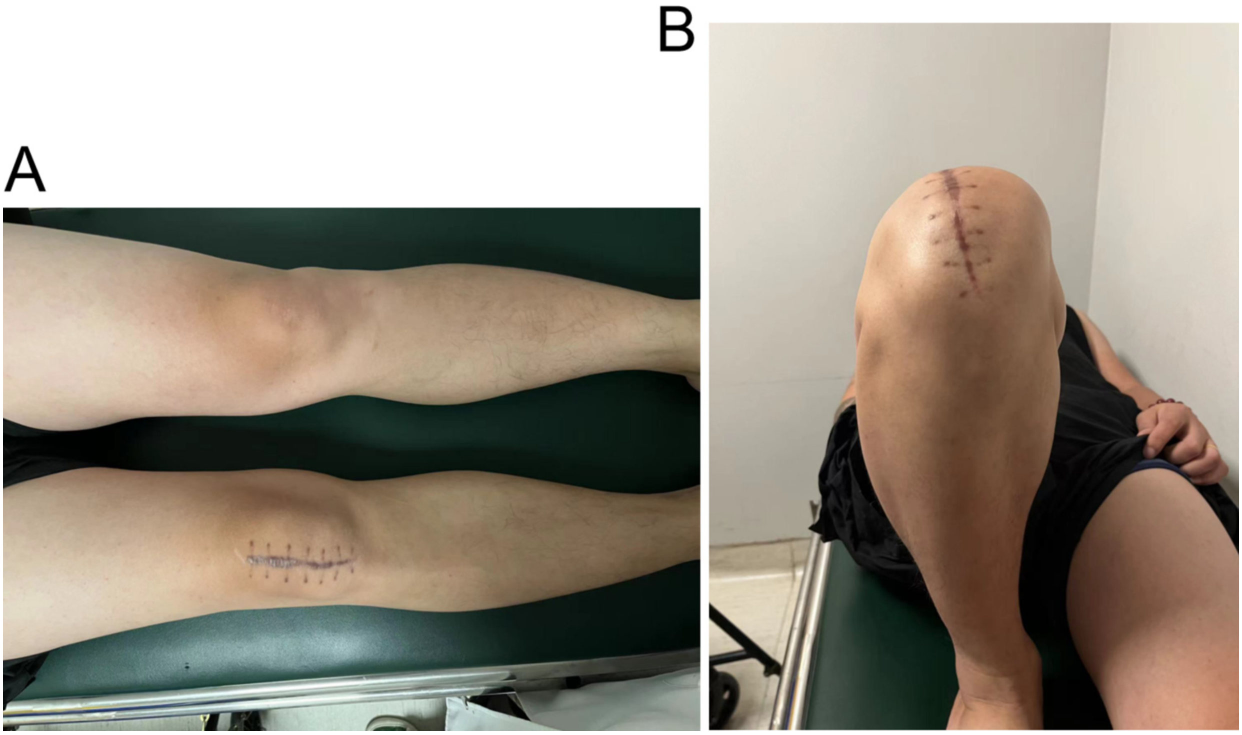

Figure 6. Stretching and bending of knee joint during postoperative rehabilitation. (a) Knee extension; (b) knee bending.

Table 3
Surgical outcome and complications.

Parameter	Combined vertical wire and mini steel plate fixation	Independent vertical wire fixation	t/χ^2	P
Operation time (min)	74.74 ± 12.45	78.45 ± 14.21	2.078	0.039
Blood loss (ml)	124.67 ± 32.21	113.49 ± 32.75	2.586	0.01
Infection rate (%)	2 (1.71%)	9 (8.26%)	3.906	0.048

3.6. Pain scores

A statistically significant difference was observed in the VAS pain scores (0–10 scale) between the two groups: 2.62 ± 1.27 vs. 3.08 ± 1.47 (t = 2.534, P = 0.012) (Figure 8). Patients who underwent combined vertical wire and mini steel plate fixation reported lower pain scores, indicating potentially improved postoperative pain management with this technique.

3.7. Return to daily activities

Analysis of the return to daily activities (Figure 9) revealed: (1) a significant difference in time to partial weight bearing (days): 22.36 ± 3.92 vs. 23.48 ± 3.49 (t = 2.291, P = 0.023); (2) no significant differences in time to full weight bearing (weeks) or return to previous activities (weeks) (P > 0.05). These results suggest that while the combined fixation technique may facilitate earlier partial weight bearing, both techniques yield comparable outcomes in terms of full weight bearing and return to previous activities.

3.8. Quality of life

Analysis of quality of life parameters using the SF-36 scale revealed no statistically significant differences between the two groups in the following domains. Physical function: 85.32 ± 6.79 vs. 84.67 ± 7.12 (t = 0.699, P = 0.485); role-physical: 83.24 ± 6.42 vs. 82.49 ± 6.48 (t = 0.873, P = 0.384); bodily pain: 79.56 ± 7.32 vs. 78.83 ± 7.68 (t = 0.732, P = 0.465); vitality: 81.23 ± 6.56 vs. 80.49 ± 6.11 (t = 0.876, P = 0.382); mental health: 84.51 ± 6.75 vs. 83.42 ± 7.24 (t = 1.172, P = 0.242) (Fig-

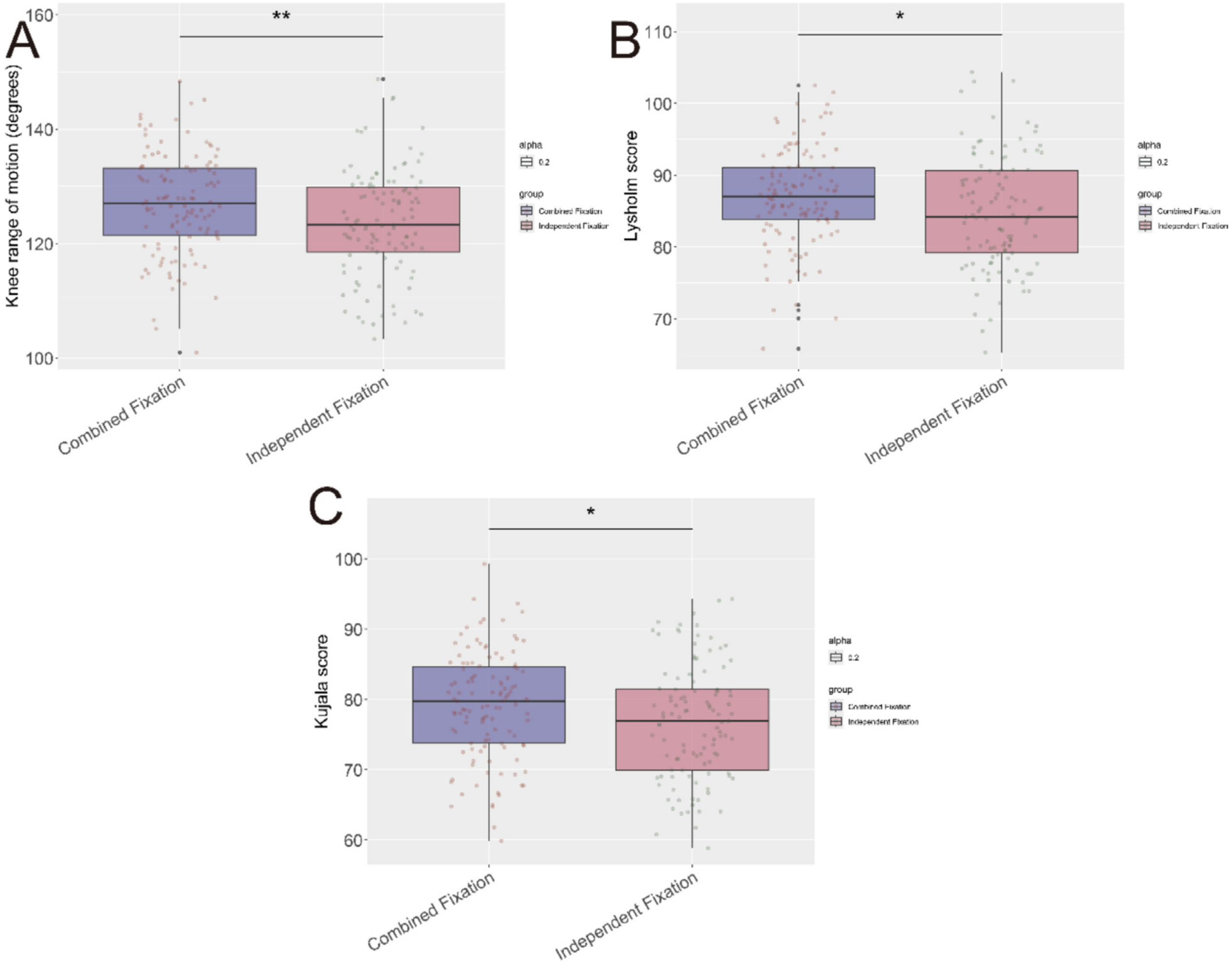

Figure 7. Functional outcomes.

ure 10). These findings demonstrate the absence of substantial differences in quality of life assessments between the two fixation techniques. The comparable scores across all evaluated domains suggest that both surgical approaches have similar impacts on patients' overall well-being.

3.9. Additional complications and adverse events

Statistical analysis did not reveal significant differences in nerve injury, implant-related complications, postoperative hemarthrosis, wound dehiscence, hardware irritation, and other complications ($P > 0.05$) between the two fixation methods (Table 4). These findings indicate comparable rates of additional complications and adverse events, suggesting similar short-term safety profiles for both approaches.

3.10. Long-term complications and reoperations

The analysis revealed statistically significant differences in osteoarthritis rate (8.55% vs. 19.27%, $\chi^2 = 4.61$, $P = 0.032$) and salvage procedure rate (2.56% vs. 10.09%, $\chi^2 = 4.284$, $P = 0.038$) between the two groups. However, no statistically significant differences were observed in chronic pain ($\chi^2 = 0.16$, $P = 0.689$), implant removal ($\chi^2 = 0.166$, $P = 0.684$), and joint stiffness ($\chi^2 = 0.026$, $P = 0.872$) (Table 5). These findings suggest that while the combined fixation technique may offer advantages in reducing long-term osteoarthritis and the need for salvage procedures, both techniques demonstrate comparable outcomes in other aspects of long-term complications and reoperations.

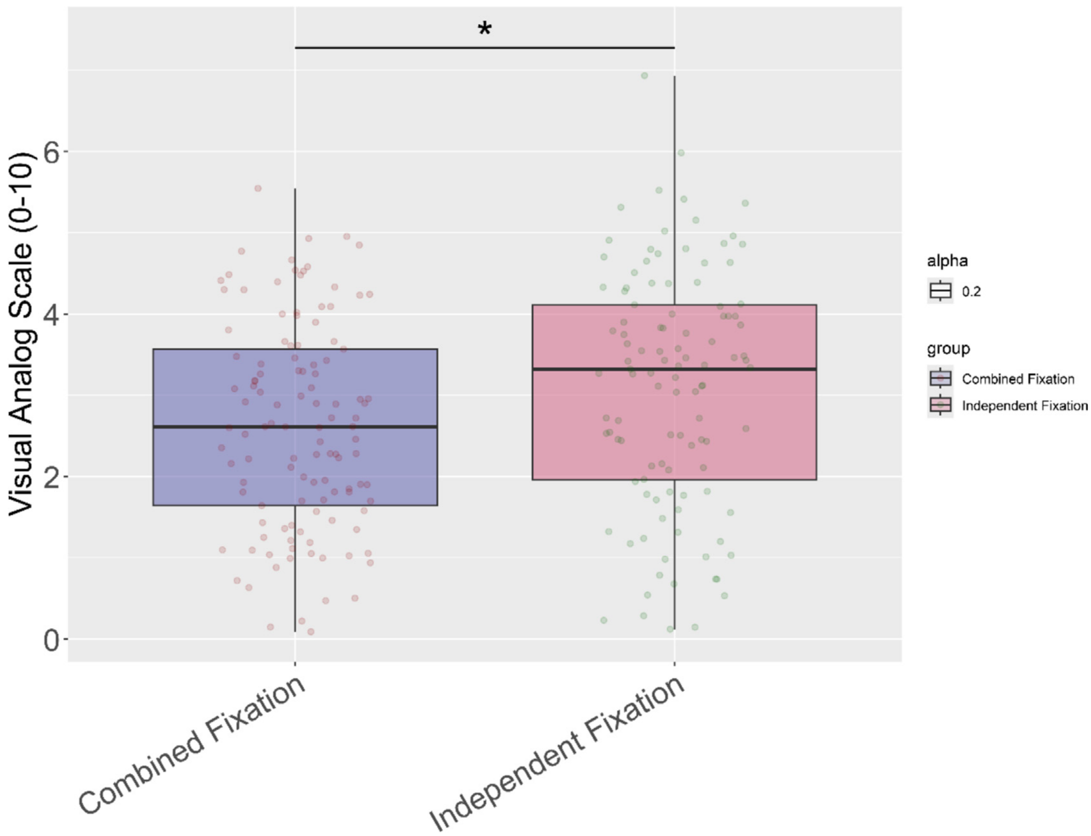

Figure 8. Pain scores.

4. Discussion

Regarding surgical outcomes and associated complications, the study revealed that combined vertical wire and mini steel plate fixation was associated with shorter operation times, higher blood loss, and a lower infection rate compared with independent vertical wire fixation. These findings may be attributed to the technical differences and distinct biomechanical properties of the fixation methods. The mini steel plate fixation may offer more efficient stabilization, contributing to reduced operation time, while the use of multiple fixation points with wires may lead to higher blood loss [17–19]. The lower infection rate associated with the combined fixation technique could indicate better soft tissue preservation and reduced risk of intra-operative contamination. However, more research is necessary to clarify the specific factors influencing these variations in surgical outcomes and complications.

In terms of functional outcomes, patients who underwent combined vertical wire and mini steel plate fixation demonstrated significantly superior knee range of motion, Lysholm score, and Kujala score compared with those treated with independent vertical wire fixation. These findings suggest that the combined fixation technique may provide enhanced biomechanical stability, thereby facilitating improved rehabilitation and functional recovery [20–22]. The mini steel plate's ability to offer additional support and enable early mobilization may contribute to the observed improvements in range of motion and functional outcomes within this cohort. The distinct mechanical advantages and load-sharing properties of the mini steel plate are hypothesized to exert a favorable influence on knee function restoration and overall rehabilitation progress [23,24]. However, further biomechanical studies and comprehensive functional assessments are warranted to validate these observations and elucidate the underlying mechanisms.

The analysis also revealed that patients who received combined vertical wire and mini steel plate fixation reported significantly lower pain levels compared with those treated with independent vertical wire fixation. These findings underscore the potential advantages of the combined fixation technique in postoperative pain management. The superior pain control associated with the combined approach may be attributed to enhanced stability and reduced micromotion at the fracture site, resulting in diminished postoperative discomfort and an improved patient experience [25–27]. None the less, additional investigation is necessary to explore the specific factors contributing to the observed differences in pain outcomes between the two fixation techniques.

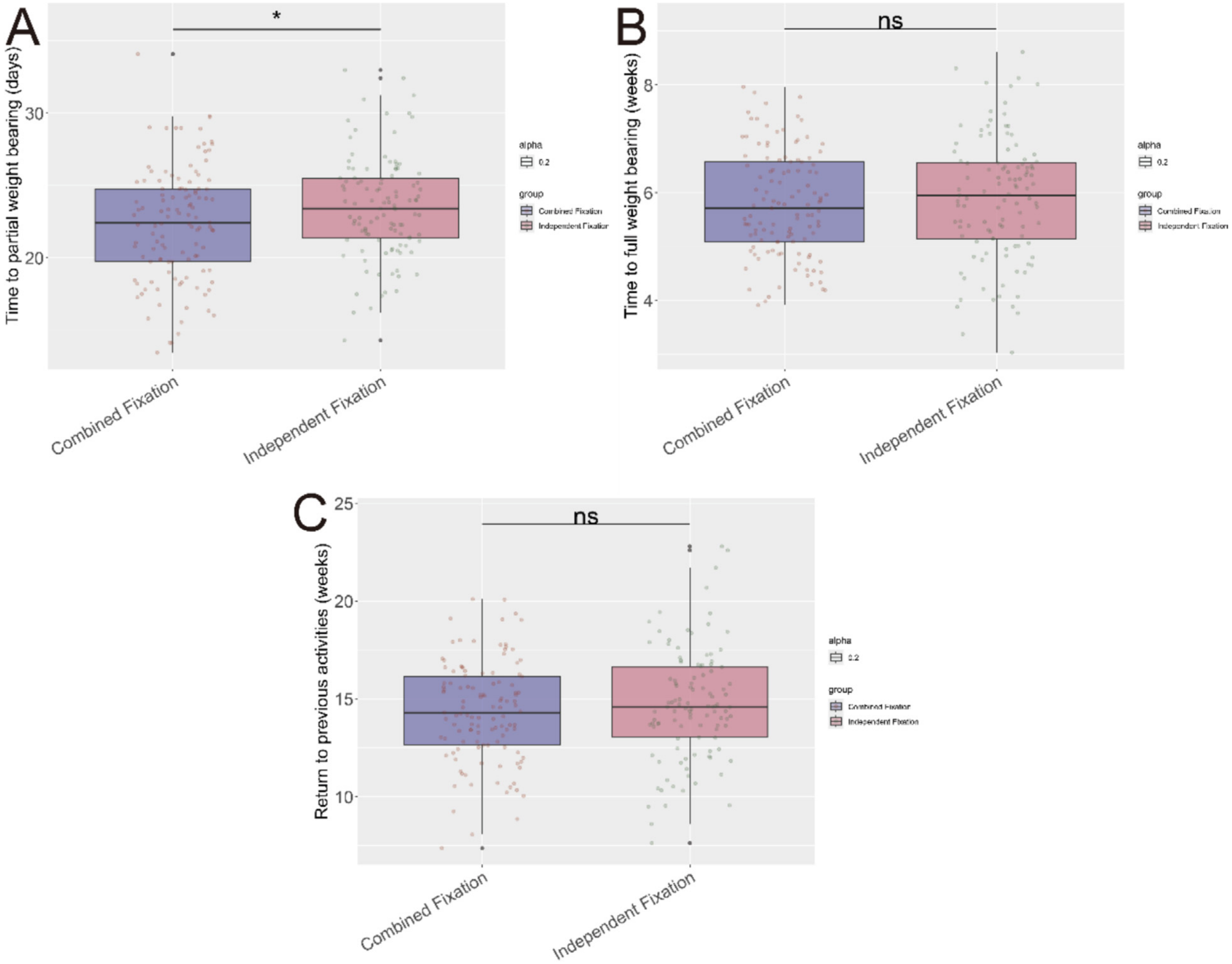

Figure 9. Return to daily activities.

Furthermore, the study demonstrated a significant disparity in osteoarthritis rates and salvage procedure rates between the two groups, with lower rates observed in the combined vertical wire and mini steel plate fixation group. These findings suggest that the biomechanical advantages of mini steel plate fixation, such as improved stability and optimized load distribution, may contribute to reduced long-term joint degeneration and a decreased need for salvage procedures [28–30]. These results suggest potential advantages of the combined fixation technique in promoting functional recovery and patient-reported outcomes. Further investigation is warranted to determine the potential protective effect of mini steel plate fixation on long-term joint health. This aspect may have important implications for the selection of optimal fixation techniques to mitigate the risk of postoperative complications and maximize long-term outcomes for patients with patellar inferior pole fractures.

It is important to acknowledge several limitations of this study, despite its valuable insights into the therapeutic effectiveness and long-term efficacy of the two internal fixation techniques. The retrospective nature of the investigation and the potential for selection bias may have influenced the results. It is important to note that the relatively short follow up period in this study may limit the assessment of long-term complications and outcomes. Future prospective studies with extended follow up durations and larger sample sizes are essential to further validate these findings and provide more robust evidence for guiding clinical decision making in the treatment of patellar inferior pole fractures.

5. Conclusions

This study's findings underscore the potential advantages of combined vertical wire and mini steel plate fixation over independent vertical wire fixation for patellar inferior pole fractures. The combined fixation technique demonstrated superior surgical outcomes, enhanced functional recovery, improved pain management, and lower long-term complication rates. These results warrant further consideration and may significantly impact the optimization of treatment strategies for these

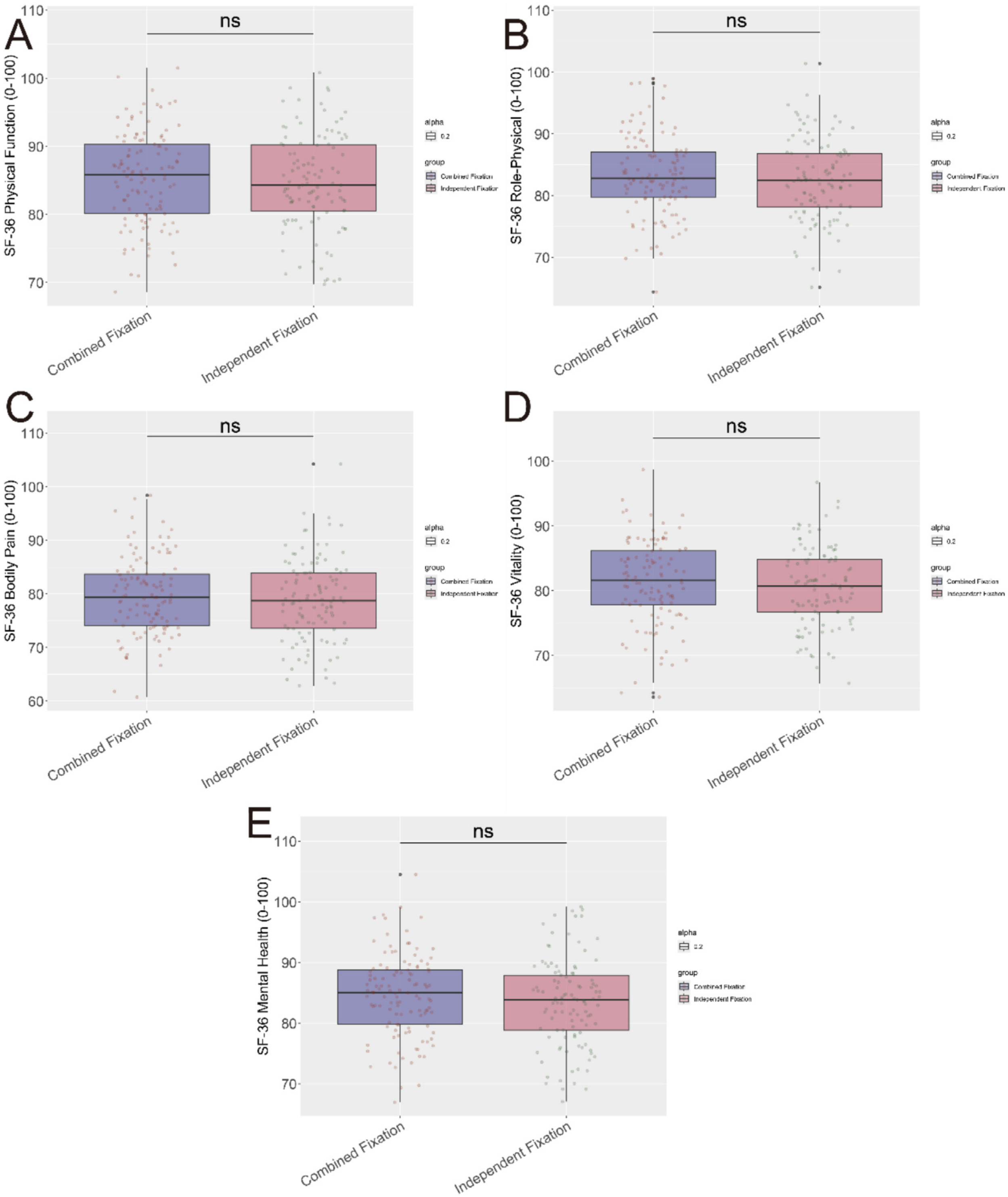

Figure 10. Quality of life assessment.

challenging fractures. Further studies investigating the biomechanical rationale and long-term benefits of the combined fixation technique are needed. Such research would provide comprehensive insights and inform evidence-based clinical practice in the management of patellar inferior pole fractures.

Table 4
Additional complications and adverse events.

Parameter	Combined vertical wire and mini steel plate fixation (n = 117)	Independent vertical wire fixation (n = 109)	χ^2	*P*
Nerve injury (yes/no)	4 (3.42%)/113 (96.58%)	5 (4.59%)/104 (95.41%)	0.012	0.914
Implant-related complications (yes/no)	9 (7.69%)/108 (92.31%)	10 (9.17%)/99 (90.83%)	0.026	0.872
Postoperative hemarthrosis (yes/no)	8 (6.84%)/109 (93.16%)	9 (8.26%)/100 (91.74%)	0.023	0.879
Wound dehiscence (yes/no)	5 (4.27%)/112 (95.73%)	6 (5.5%)/103 (94.5%)	0.015	0.904
Hardware irritation (yes/no)	9 (7.69%)/108 (92.31%)	10 (9.17%)/99 (90.83%)	0.026	0.872
Other complications (yes/no)	14 (11.97%)/103 (88.03%)	15 (13.76%)/94 (86.24%)	0.042	0.838

Table 5
Long-term complications and reoperations.

Parameter	Combined fixation group (n = 117)	Independent fixation group (n = 109)	χ^2	*P*
Osteoarthritis rate (yes/no)	10 (8.55%)/107 (91.45%)	21 (19.27%)/88 (80.73%)	4.61	0.032
Chronic pain (yes/no)	11 (9.4%)/106 (90.6%)	13 (11.93%)/96 (88.07%)	0.16	0.689
Implant removal (yes/no)	15 (12.82%)/102 (87.18%)	17 (15.6%)/92 (84.4%)	0.166	0.684
Joint stiffness (yes/no)	9 (7.69%)/108 (92.31%)	10 (9.17%)/99 (90.83%)	0.026	0.872
Salvage procedure (yes/no)	3 (2.56%)/114 (97.44%)	11 (10.09%)/98 (89.91%)	4.284	0.038

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Author contributions

Y.D. and B.M.L. were involved in the conception and design, and analysis and interpretation of the data; W.C.H., L.H.W., and Y.X.D. contributed to the drafting of the paper, and revised it critically for intellectual content; B.M.L. approved the final version of the manuscript.

CRediT authorship contribution statement

Yan Dong: Writing – review & editing, Writing – original draft, Data curation, Conceptualization. **Weichun Huang:** Methodology, Investigation, Formal analysis. **Lihong Wei:** Visualization, Validation, Supervision. **Yingxun Du:** Software, Resources, Methodology. **Bingmin Lin:** Writing – review & editing, Writing – original draft, Project administration, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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