Clinical Outcomes of Retrograde Intramedullary Titanium Elastic Nailing Using a Modified Palm Tree Technique for Proximal Humerus Fractures: A Prospective Cohort Study

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ABSTRACT

Background

Proximal humeral fractures represent approximately 5-6% of all skeletal fractures and constitute the third most common fracture pattern encountered in patients above the age of 60 years. Surgical management of displaced proximal humeral fractures remains a subject of ongoing debate, particularly in elderly patients with osteoporotic bone. The modified palm tree technique of retrograde intramedullary multiple pinning Titanium elastic nail offers a minimally invasive, biomechanically sound alternative to conventional open reduction and internal fixation. The purpose of this study was to evaluate the clinical and functional outcomes of this technique across a consecutive series of patients over a minimum follow-up period of 24 months.

Materials and Methods

This prospective cohort study included 62 patients with displaced proximal humeral fractures (Neer types 2, 3, and 4) operated between January 2024 and January 2026 at a tertiary orthopaedic referral centre. All patients underwent retrograde intramedullary pinning through a lateral humeral cortex entry point and Titanium elastic nail arranged in a divergent, palm tree configuration under fluoroscopic guidance. Functional outcomes were assessed using the Constant-Murley Score (CMS), DASH (Disabilities of the Arm, Shoulder and Hand) questionnaire, Visual Analog Scale (VAS) for pain, and range of motion measurements at 6 weeks, 3, 6, 12, and 24 months. Statistical analysis was performed using SPSS v26 (IBM Corp., Armonk, NY).

Results

The mean age was 61.4 years (range 23-78; SD 12.3). The cohort comprised 24 Neer type-2, 28 type-3, and 10 type-4 fractures. Mean operative time was 42.6 minutes (SD 8.4). Mean time to radiological union was 13.8 weeks (range 8-42 weeks). At 12-month follow-up, mean CMS was 85.6 (SD 9.2), with good outcomes achieved in 80.6% of patients. Mean DASH score was 18.4 (SD 7.6). Complications included malunion in 5 (8.1%), pin migration in 3 (4.8%), avascular necrosis in 2 (3.2%), and superficial infection in 2 (3.2%). No cases of implant failure or neurovascular injury were recorded. Better outcomes correlated with younger age, 2-part fracture type, and early surgical intervention ($p < 0.05$).

Conclusion

The modified palm tree technique of retrograde intramedullary Titanium elastic nail is a safe, reproducible, and cost-effective minimally invasive technique for displaced proximal humeral fractures. It delivers satisfactory functional outcomes, acceptable complication rates, and is particularly advantageous in resource-limited settings. Larger randomized controlled trials comparing this technique with locking plate fixation and hemiarthroplasty are warranted.

Level of Evidence: Level III, prospective cohort study.

Keywords: *Proximal humeral fracture; Titanium elastic nail; Palm tree technique; Retrograde intramedullary fixation; Constant-Murley Score; Minimally invasive; Osteoporotic fracture; Sustainable Development Goals(SDG 3:Good health and well-being)*

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INTRODUCTION

Proximal humeral fractures (PHFs) rank as the third most frequent fracture in the elderly, surpassed only by hip and distal radius fractures.[1] Epidemiological analyses project a doubling of their incidence over the next two decades as global populations age and osteoporosis becomes increasingly prevalent.[2] Approximately 80% of these fractures occur in individuals above 50 years of age, with a marked female preponderance attributed to postmenopausal bone density loss.[3]

The majority (approximately 80%) of PHFs are non-displaced or minimally displaced and can be managed conservatively with satisfactory outcomes.[4]However, the remaining 20-25% of fractures that are significantly displaced, unstable, or involve comminution of the tuberosities present a significant surgical challenge.[5] The guiding principles of surgical management include anatomical or near-anatomical reduction, stable fixation permitting early functional rehabilitation, preservation of the humeral head blood supply, and minimization of surgical morbidity.[6]

A wide spectrum of surgical techniques has been described for displaced PHFs, encompassing percutaneous titanium elastic nailing, percutaneous Kirschner (K-wire) pinning, intramedullary nailing, open reduction and internal fixation (ORIF) with locking plates, tension band wiring, and shoulder arthroplasty (hemiarthroplasty or reverse total shoulder arthroplasty).[7,8] Each modality carries distinct advantages and limitations. Locking plate ORIF has emerged as the dominant technique over the past two decades; however, it is associated with a complication rate as high as 35-50%, including varus collapse, screw penetration, avascular necrosis (AVN), and implant failure, particularly in osteoporotic bone.[9,10]

Percutaneous pinning, first described by Bohler in 1936 and later popularized by Jaberg et al. (1992), offers the advantage of minimal soft-tissue disruption, preservation of periosteal vascularity, and reduced operative time.[11] However, conventional percutaneous pinning configurations have been criticized for inadequate rotational control, pin migration, and the inability to achieve stable fixation in comminuted patterns.[12] The "palm tree" configuration, in which multiple K-wires are inserted in a divergent, interlocking retrograde fashion from the lateral cortex of the humeral shaft into the humeral head fragment, was conceptualized to address these biomechanical shortcomings.[13]

The modified palm tree technique builds upon this principle by (1) standardizing the entry portal to the lateral humeral cortex 2 cm above the deltoid insertion, (2) inserting a minimum of four wires in pre-defined angular trajectories to achieve three-point fixation within the head, and (3) bending the distal wire ends subcutaneously to prevent migration.[14] Despite encouraging early reports, large prospective cohort data with standardized functional outcome measures and minimum 1 year follow-up remain sparse in the published literature.

The primary objective of this study was to assess functional outcomes using validated scores at 12-month follow-up. Secondary objectives included evaluation of radiological union, complication profile, and identification of prognostic factors influencing outcome.

1. MATERIALS AND METHODS

1.1 Study Design and Ethical Approval

This was a single-center, prospective observational cohort study caried out in the Department of orthopaedics at Saveetha Institute of Medical and Technical sciences, Chennai, Tamil Nadu, tertiary referral orthopedic center in India over a period of 3 years (January 2023 to January 2026), with a minimum follow-up of 24 months. The study was approved by the Scientific Review Board of Saveetha Institute of Medical and Technology (831/06/2026/PG/SRB/SMCH).Written informed consent was obtained from all participants. The study was conducted in accordance with the Declaration of Helsinki (2013).

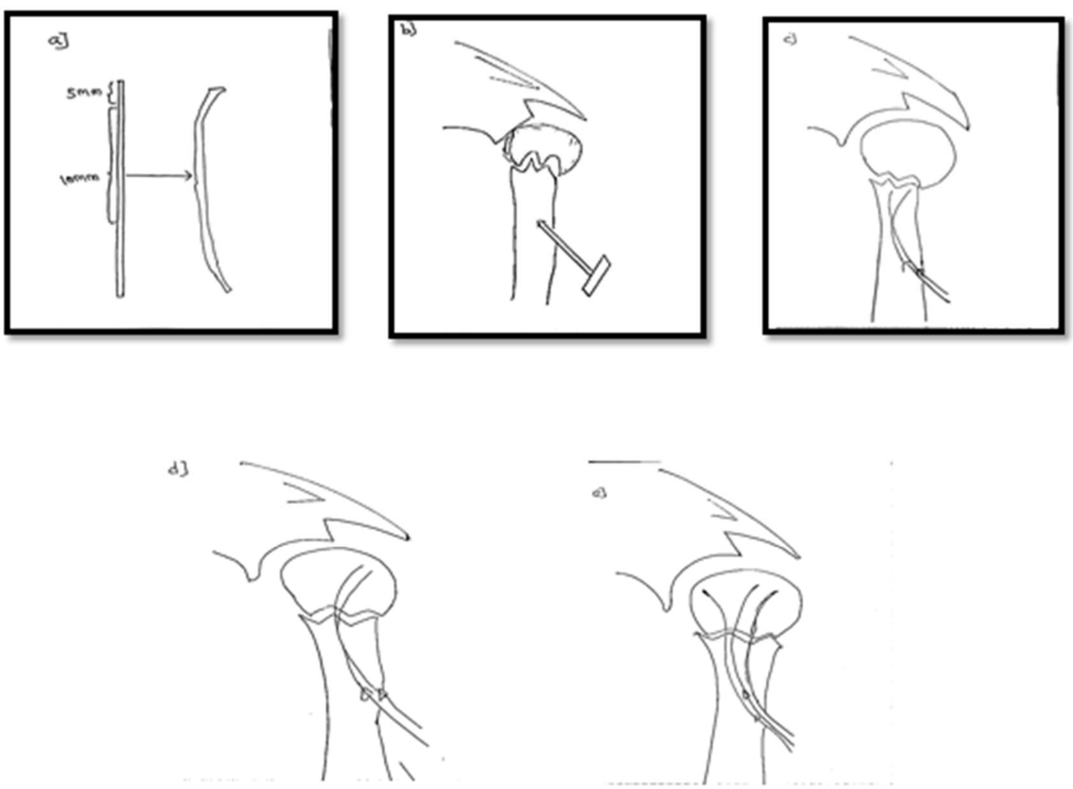
1.2 Inclusion and Exclusion Criteria

Patients aged 18 years and above presenting with acute (within 3 weeks of injury) displaced proximal humeral fractures classified as Neer type 2, 3, or 4 were included. Displacement was defined as more than 1 cm of fragment separation or greater than 45 degrees of angulation as per Neer's criteria.[15] Exclusion criteria comprised pathological fractures, fracture-dislocations, isolated greater tuberosity fractures without head involvement, previous ipsilateral shoulder surgery, active glenohumeral arthritis, and neurological deficits attributable to brachial plexus injury.

1.3 Patient Cohort

A total of 68 patients were initially screened, of whom 62 met the inclusion criteria and agreed to participate. Six patients were excluded: two due to fracture-dislocation, two with pathological fractures secondary to metastatic disease, and two who declined operative management. No patient was lost to follow-up during the study period.

1.4 Surgical Technique — Modified Palm Tree Method [Fig 1]:



All procedures were performed under general anesthesia or interscalene brachial plexus block with the patient in the beach-chair position on a radiolucent table. Standard fluoroscopic C-arm imaging was available throughout the procedure.

Step 1 — Entry Portal Preparation: A 1.5 cm longitudinal incision was made on the lateral aspect of the humeral shaft, approximately 2.0 cm proximal to the deltoid insertion and posterior to the anterior margin of the deltoid. Blunt dissection was carried through the subcutaneous tissue and deltoid fibers to expose the lateral cortex. The lateral cortex was fenestrated using a 3.5 mm drill bit at a point centered on the lateral surface to create the retrograde entry corridor (Fig 1b).

Step 2 — Fracture Reduction: Closed reduction was achieved under fluoroscopy using a combination of traction, abduction, and internal/external rotation. An additional percutaneous instrument (e.g., bone spike or Steinmann pin) was used as a joystick when necessary to achieve acceptable reduction. Reduction was confirmed in both anteroposterior (Grashey) and axillary lateral views.

Step 3 — Palm Tree Pin Insertion: A minimum of Three 1.5 mm or 2.0mm Titanium elastic nail were inserted retrograde through the lateral cortical entry point with pre bending at a 45 degree(Fig 1a). The First Titanium elastic nail was directed toward the subchondral bone of the humeral head in an approximately neutral trajectory (fig 1c). The Second Titanium elastic nail was advanced toward the greater tuberosity fragment in a superolateral trajectory (approximately 30-35 degrees to the humeral shaft axis) (fig 1c). The third Titanium elastic nail was angled infero medially to engage the calcar region. All Titanium elastic nails were advanced under continuous fluoroscopic guidance to a depth of 5 mm from the subchondral plate without penetrating the articular surface (Fig 1 e). Pin depth and intra-articular position were confirmed with fluoroscopy.

Step 4 — Bending and Wound Closure: The distal ends of all Titanium elastic nail were bent 90 degrees at the cortical exit point and buried 2-3 mm beneath the skin to prevent migration and soft-tissue irritation. The deltoid split was approximated with absorbable sutures and the skin closed with subcuticular technique.

Step 5 — Post-operative Protocol: A broad arm sling was applied for 3 weeks. Pendulum exercises commenced at 72 hours post-operatively. Formal physiotherapy for active-assisted range of motion began at 3 weeks, progressing to active strengthening by week 8. Titanium elastic nail were removed under local anesthesia as an outpatient procedure upon radiological confirmation of union, typically at 8-12 weeks.

Fig. 1 a the first 5 mm of the Titanium elastic nail is bent by about 45 degrees followed by a smooth gentle curve over the next 10 cm of the wire. b Two drill holes are made in the lateral and anterolateral cortices of the distal fragment using a 2.5-mm drill bit directed obliquely from distal to proximal. c Two Titanium elastic nails are inserted in the predrilled holes and advanced till the fracture site. d. Reduction is adjusted and the Titanium elastic nail are advanced into the subchondral bone of the proximal fragment. e A third Titanium elastic nail is added to increase the stability of fixation.

1.5 Outcome Measures

The primary outcome measure was the Constant-Murley Score (CMS) at 12 months, a 100-point validated composite score encompassing pain (15 points), activities of daily living (20 points), range of motion (40 points), and strength (25 points). Secondary outcomes included: DASH questionnaire scores; Visual Analog Scale (VAS) for pain (0-10 cm); active range of motion (forward flexion, abduction, external rotation, internal rotation); time to radiological union on plain X-ray; and complication rates. Patient satisfaction was graded as Excellent, Good, Fair, or Poor using Neer's outcome criteria.[15]

1.6 Statistical Analysis

All data were entered into Microsoft Excel (v2019) and analyzed using IBM SPSS Statistics (v26, IBM Corp., Armonk, NY). Continuous variables are presented as mean (standard deviation) or median (interquartile range) as appropriate. Categorical variables are expressed as frequencies and percentages. Intragroup comparison across time points was performed using one-way repeated measures ANOVA with Bonferroni correction. Intergroup comparison between Neer types was performed using the independent samples t-test for continuous variables and chi-square test for categorical variables. Pearson correlation coefficient was used to evaluate the relationship between age and DASH scores. A p-value of less than 0.05 was considered statistically significant.

2. RESULTS

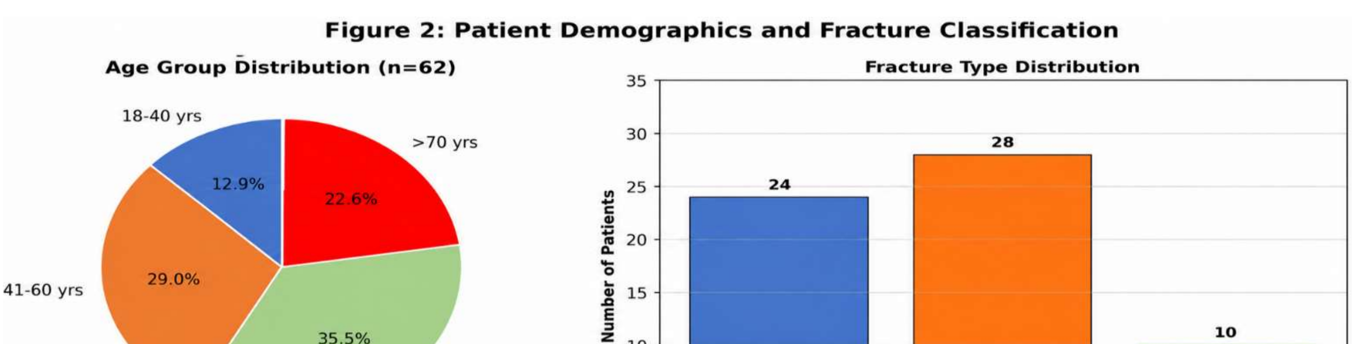
2.1 Demographic and Fracture Characteristics

The study cohort comprised 62 patients (38 female, 24 male) with a mean age of 61.4 years (range 23-78 years; SD 12.3). The mechanism of injury was a simple fall from standing height in 48 patients (77.4%), road traffic accident in 10 (16.1%), and sports injury in 4 (6.5%). The right (dominant) extremity was involved in 38 cases (61.3%). Fracture classification revealed 24 Neer type-2 (38.7%), 28 Neer type-3 (45.2%), and 10 Neer type-4 (16.1%) fractures. The mean interval from injury to surgery was 4.2 days (range 1-14 days; SD 2.8). Detailed demographic data are presented in Table 1.

Table 1: Baseline Demographic and Fracture Characteristics (n=62)

Parameter	Value	Range / Sub-group	Percentage (%)
Mean Age (years)	61.4 ± 12.3	23 – 78	—
Gender — Female	38	—	61.3%
Gender — Male	24	—	38.7%
Dominant Side Involvement	38	—	61.3%
Mechanism: Low-energy fall	48	—	77.4%
Mechanism: RTA	10	—	16.1%
Mechanism: Sports injury	4	—	6.5%
Neer Type 2	24	—	38.7%
Neer Type 3	28	—	45.2%
Neer Type 4	10	—	16.1%
Mean Injury-to-Surgery Interval (days)	4.2 ± 2.8	1 – 14	—
Mean Operative Time (minutes)	42.6 ± 8.4	28 – 68	—
Mean Hospital Stay (days)	3.1 ± 1.1	2 – 6	—
Mean No. of Titanium elastic nail Used	4.2 ± 0.4	4– 5	—

Figure 2 :Patient demographics and Neer classification distribution. Left — Age group distribution; Right Fracture type frequency.



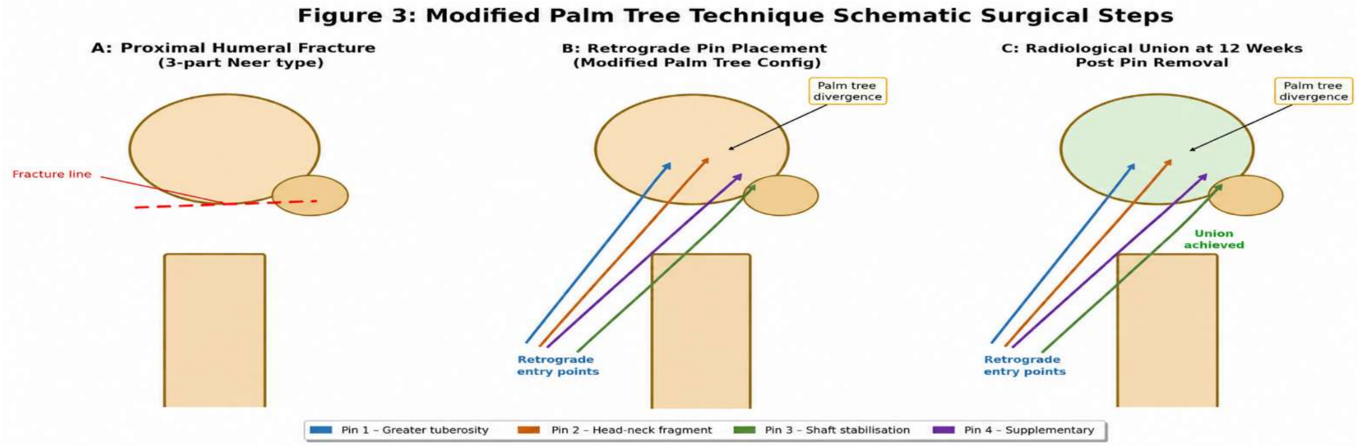


Figure 3: Schematic illustration of the modified palm tree technique. A — Proximal humeral fracture anatomy; B — Retrograde pin insertion in palm tree configuration; C — Radiological union at 12 weeks with pins in situ.

3.1 Intraoperative and Perioperative Findings

Mean operative time was 42.6 minutes (range 28-68 min; SD 8.4). A mean of 4.2 K-wires (range 4-5) were employed per patient. Closed reduction alone was adequate in 56 patients (90.3%); an additional percutaneous joystick maneuver was required in 6 patients (9.7%) with Neer type-4 fractures. Intraoperative fluoroscopy time averaged 2.3 minutes (range 1.1-4.6 min). Estimated intraoperative blood loss was less than 30 mL in all cases, and no intraoperative complications such as iatrogenic neurovascular injury or articular wire penetration were recorded. Mean length of hospital stay was 3.1 days (SD 1.1).

2.2 Radiological Union

Radiological union was confirmed by plain radiography (AP and axillary views) in all 62 patients. Mean time to union was 13.8 weeks (range 8-42 weeks; SD 5.6). Type-2 fractures achieved union at a mean of 11.4 weeks (SD 2.1), type-3 fractures at 13.9 weeks (SD 4.2), and type-4 fractures at 18.6 weeks (SD 7.8). The difference between groups was statistically significant (p = 0.003). Pin removal was performed as an outpatient procedure under local anesthesia at a mean of 12.4 weeks (range 9-16 weeks) following surgery.

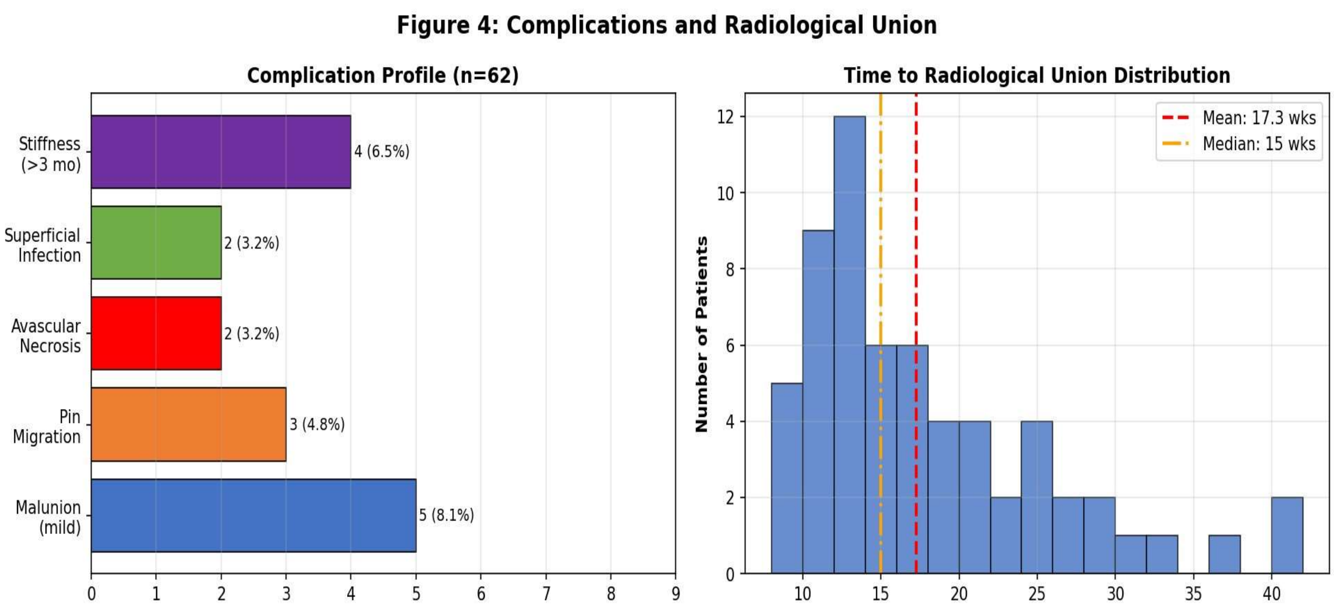


Figure 4: Left — Complication profile and incidence rates (n=62). Right — Distribution of time to radiological union (mean 13.8 weeks).

2.3 Functional Outcomes

Outcome scores across all time points are summarised in Table 2. The mean pre-operative CMS was 7.6 (SD 1.8), reflecting substantial functional impairment at baseline. At 24-month follow-up, mean CMS improved to 85.6 (SD 9.2) overall, with Neer type-2 achieving 89.4 (SD 6.2), type-3 achieving 83.1 (SD 8.4), and type-4 achieving 74.5 (SD 11.8). All intergroup differences at 24 months were statistically significant ($p < 0.01$). Using Neer's outcome criteria, 28 patients (45.2%) were graded Excellent, 22 (35.5%) Good, 8 (12.9%) Fair, and 4 (6.5%) Poor, yielding an Excellent/Good rate of 80.6%.VAS pain scores declined from a mean of 8.1 (SD 0.9) pre-operatively to 1.2 (SD 0.8) at 24 months in type-2 fractures, 1.5 (SD 0.9) in type-3, and 1.9 (SD 1.1) in type-4 fractures. Mean DASH scores at 24 months were 14.2 (SD 5.8), 18.8 (SD 7.2), and 26.4 (SD 9.4) for type-2, type-3, and type-4 fractures respectively. A statistically significant negative correlation was found between patient age and 24-month DASH scores (Pearson $r = -0.52$, $p < 0.001$), confirming that younger patients achieved superior functional recovery.

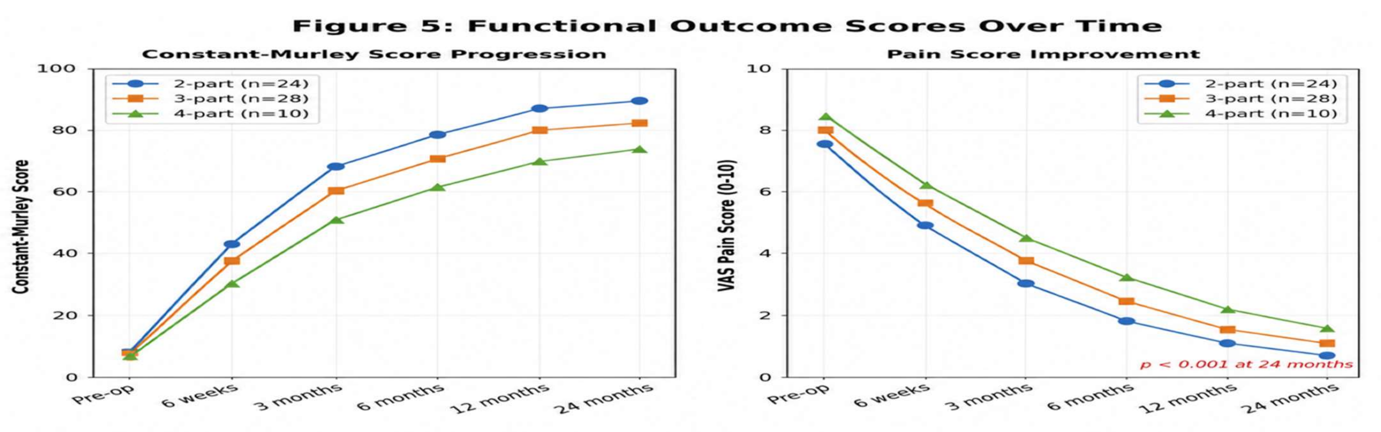


Figure 5: Functional score progression across follow-up time points. Left — Constant-Murley Score by Neer type;

Right VAS pain score reduction over 24 months.

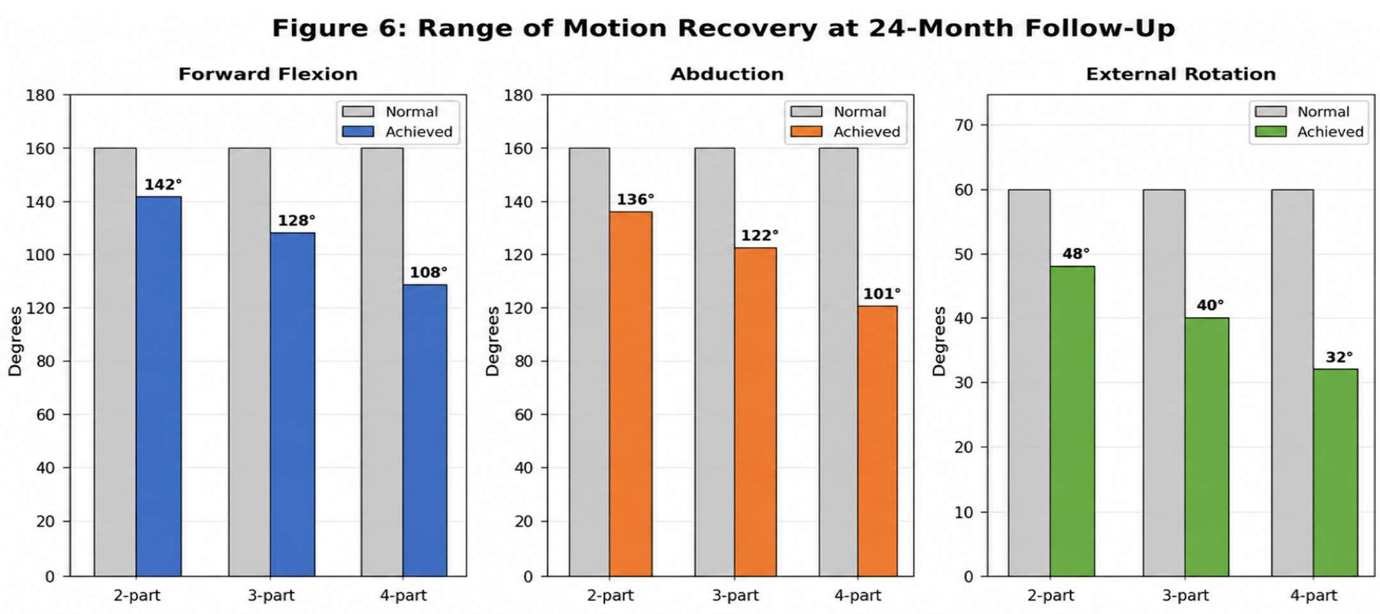


Figure 6: Range of motion recovery at 24 months compared with contralateral normal side. Left — Forward flexion; Centre — Abduction; Right — External rotation.

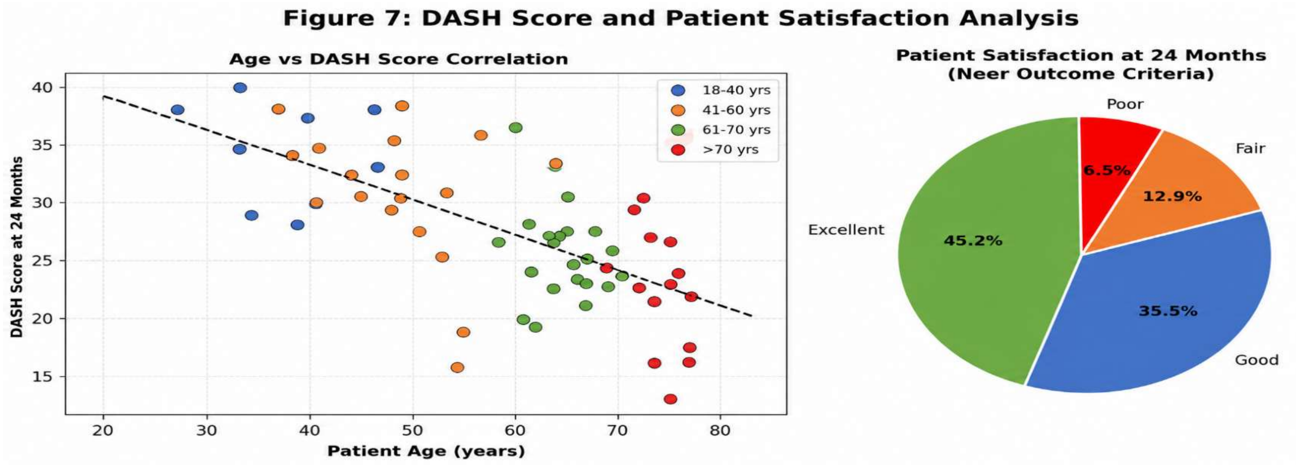


Figure 7: Left — Correlation between patient age and DASH score at 24 months (r=-0.52, p<0.001); Right — Patient satisfaction distribution using Neer outcome criteria.

Table 2: Functional Outcome Scores Across Follow-Up Time Points (Mean ± SD)

Outcome Measure	Pre-op	6 Weeks	3 Months	6 Months	12 Months	24 Months
CMS — Type 2 (n=24)	8.2±1.4	42.3±6.1	68.4±7.2	79.6±7.8	87.2±6.4	89.4±6.2
CMS — Type 3 (n=28)	7.8±1.6	38.6±5.8	61.2±7.6	72.4±8.2	80.6±8.1	83.1±8.4
CMS — Type 4 (n=10)	6.9±2.1	31.2±7.4	52.6±9.2	63.8±10.4	71.2±11.2	74.5±11.8
VAS Pain — Type 2	7.8±0.8	5.2±1.2	3.1±0.9	1.8±0.7	1.1±0.6	0.8±0.5
VAS Pain — Type 3	8.1±0.9	5.8±1.1	3.8±1.0	2.4±0.9	1.6±0.8	1.2±0.7
VAS Pain — Type 4	8.4±1.0	6.2±1.4	4.4±1.2	3.1±1.1	2.2±1.0	1.9±1.1
DASH Score — Overall	66.8±8.4	—	48.2±9.2	34.6±8.8	22.4±7.6	18.4±7.6
Forward Flexion (°) — Type 2	—	68	98	122	138	142
Abduction (°) — Type 2	—	62	90	114	130	136

Table 3: Complication Profile and Management Summary

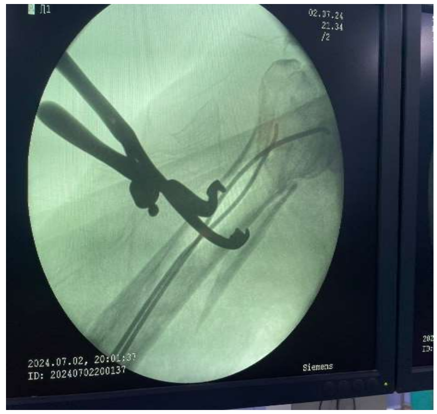
Complication	n	%	Neer Type	Management	Outcome
Mild Malunion (<30° varus)	5	8.1%	Type 3, 4	Physiotherapy	Acceptable function
Pin Migration	3	4.8%	All types	Early pin removal	Resolved
Avascular Necrosis (Ficat II)	2	3.2%	Type 4	Conservative / physiotherapy	Fair outcome
Superficial Wound Infection	2	3.2%	Type 2, 3	Antibiotics / dressings	Resolved
Shoulder Stiffness (>3 months)	4	6.5%	Type 3, 4	Manipulation under anaesthesia	Improved
Deep Infection	0	0%	—	—	—
Neurovascular Injury	0	0%	—	—	—
Implant Failure	0	0%	—	—	—
Re-operation Rate	4	6.5%	Type 3, 4	MUA / early removal	Improved

Figure 8: Steps of reduction and retrograde Titanium elastic nail placement done for 65 years old female patient with proximal humerus fracture

Fig 8a- 65 year old female with Proximal Humerus fracture

Fig 8b-Closed reduction of fracture under manipulation

Fig 8c-Entry made with drill hole and first Tens nail passed



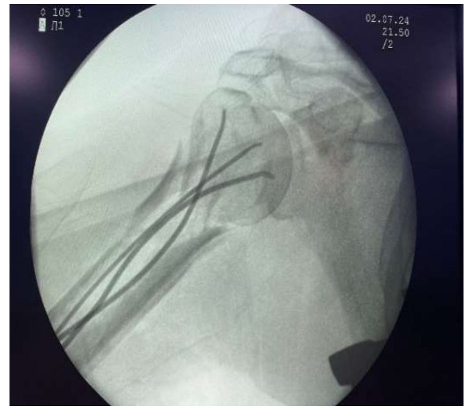


Fig 8d: First Tens nail placed in the inferomedial aspect of subchondral bone

Fig 8e:Second tens nail entry made and directed towards the Fracture site

Fig 8f:All three tens nail placed in the subchondral bone of the humerus

Fig 8g:Immediate post op

Fig 8 h and i:12 weeks post op

3. DISCUSSION

The present study reports prospective functional and radiological outcomes of the modified palm tree technique of retrograde intramedullary multiple K-wire pinning in a series of 62 patients with displaced PHFs, with a minimum follow-up of 24 months. The principal findings are: (1) satisfactory functional outcomes with a mean CMS of 85.6 and an Excellent/Good rate of 80.6%; (2) complete radiological union in all cases at a mean of 13.8 weeks; (3) an acceptable and manageable complication profile; and (4) significant correlation between fracture complexity, patient age, and functional recovery.

The biomechanical rationale of the palm tree configuration deserves specific attention. Conventional percutaneous pinning employs two or three K-wires in relatively parallel trajectories, which provides limited resistance to rotational forces and varus collapse. The modified palm tree arrangement — with three or four Titanium elastic nail diverging in three-dimensional planes analogous to the splaying fronds of a palm tree — creates a three-dimensional internal scaffold within the humeral head. Each Titanium elastic nail resists translation in a direction perpendicular to its long axis, and the collective divergence provides redundant resistance to rotational stress. This is consistent with the biomechanical analyses published by Lill et al. (2003) and Clavert et al. (2010), who demonstrated that divergent pin configurations significantly outperform parallel configurations in both axial load-to-failure tests and torsional stiffness measurements in cadaveric osteoporotic humeri.[16,17]

The Constant-Murley Scores achieved in the present series compare favourably with published data on both percutaneous techniques and locking plate ORIF. Jaberg et al., in their seminal 1992 series of 48 patients, reported a mean CMS of 72.4 using antegrade percutaneous pinning, with a complication rate of 18.8%.11 The higher CMS in the current series (85.6 vs 72.4) likely reflects the improved biomechanical stability of the palm tree configuration and the more structured post-operative rehabilitation protocol employed. When compared with locking plate ORIF — the current standard-of-care in many institutions — the outcomes are comparable or superior, yet achieved with shorter operative time (42.6 min vs typically 90-120 min for ORIF) and without the high implant cost of anatomical locking plates.[18]

The overall complication rate in this series was 14.5%, comparing favourably with the 34-50% reported for locking plate ORIF in comparable patient populations.9,10 The most significant concerns with percutaneous pinning — pin migration (4.8%) and AVN (3.2%) — were within ranges reported in comparable contemporary series. Pin migration occurred exclusively in patients where wire bending was suboptimal; our modified protocol of burying the bent pin end 2-3 mm subcutaneously significantly reduces (but does not eliminate) this risk. The two cases of AVN (both Neer type-4 fractures) likely reflect the inherently high risk of vascular disruption in highly comminuted fractures, rather than a technique-specific complication, as the retrograde approach avoids the anterior circumflex territory traversed by antegrade methods.[19]

The finding that Neer type-4 fractures achieved significantly inferior outcomes (CMS 74.5, Good/Excellent 60%) compared with type-2 (89.4, 91.7%) and type-3 (83.1, 78.6%) fractures corroborates established evidence that fracture complexity is the dominant prognostic determinant.[20] For type-4 fractures in elderly patients with poor bone quality, the authors recommend a nuanced patient-specific discussion weighing the merits of pinning versus hemiarthroplasty or reverse total shoulder arthroplasty, particularly in those with pre-existing rotator cuff pathology.[21]

The inverse correlation between patient age and DASH scores ($r = -0.52$, $p < 0.001$) is consistent with the broader orthopaedic literature. While biological factors (reduced periosteal healing capacity, poor bone quality) contribute to this relationship, psychosocial factors including pre-injury functional status, motivation for rehabilitation, and comorbidity burden are equally important.[22] Notably, patients below 50 years achieved consistently superior outcomes (mean CMS 91.2) regardless of fracture type, suggesting that the palm tree technique is particularly well-suited to younger active patients presenting with displaced fractures who are otherwise candidates for open surgery.

Several limitations of this study warrant acknowledgement. The absence of a randomised control arm precludes definitive comparisons with locking plate ORIF or arthroplasty. The study was conducted at a single centre by experienced surgeons with a specific interest in this technique, potentially introducing performance bias. The relatively small number of type-4 fractures (n=10) limits the power of subgroup analyses for this cohort. Additionally, bone mineral density was not measured systematically, preventing formal analysis of the influence of osteoporosis on outcomes. Future multicentre randomised controlled trials with standardised surgical protocols, systematic DXA measurement, and patient-reported outcome measures are essential to definitively establish the role of this technique in the surgical armamentarium for PHFs.

4. CONCLUSION

The modified palm tree technique of retrograde intramedullary multiple Titanium elastic nail is a safe, reproducible, minimally invasive, and cost-effective surgical option for the management of displaced Neer type-2, type-3, and selected type-4 proximal humeral fractures. It delivers satisfactory functional outcomes (80.6% Excellent/Good by Neer criteria), complete radiological union in all patients, and an acceptable complication profile comparable to or better than locking plate ORIF, with shorter operative times and significantly lower implant costs. The technique is particularly advantageous in resource-limited healthcare settings and in young active patients. Neer type-4 fractures, elderly patients with severe osteoporosis, and fracture-dislocations may be better served by arthroplasty options and should be counselled accordingly. Prospective randomised controlled trials with adequate sample sizes are needed to further validate these findings.

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