

Original Research Article

Outcomes of supracondylar humerus fractures treated with Dorgan's pinning and extension casting at 150°: a retrospective cohort study of 112 children with 5-year follow-up

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ABSTRACT

Background: Objectives were to evaluate the long-term clinical and functional outcomes of the Dhavani Technique-a minimally invasive approach combining closed reduction, Dorgan's lateral cross pinning, and 150° extension casting-in the management of paediatric supracondylar humerus fractures.

Methods: A 10-year multicenter retrospective cohort study conducted across three tertiary care centres. Between 2015 and 2024, 112 children with closed supracondylar humerus fractures (75 Gartland type II and 37 type III) were treated using closed reduction followed by Dorgan's lateral cross-pinning without incision and post-operative immobilisation with casting at 150° elbow extension. All procedures were performed within four days of injury. Patients were followed for a mean duration of five years. Outcome measures included operative time, neurovascular complications, pin site infections, plaster-related issues, residual deformity, physiotherapy requirement, and final functional range of motion.

Results: No post-fixation neurovascular complications were observed. Operative time was notably shorter compared with traditional crossed pinning techniques. Superficial K-wire site infections occurred in seven cases (6.25%) and were managed conservatively. Plaster slippage occurred in nine cases; all successfully converted to full casting at two weeks without further issues. Cubitus varus developed in two patients (1.8%). Twenty-one children (18.75%) required physiotherapy for complete motion recovery. At final follow-up, all patients achieved full functional range of motion with no lasting functional limitations.

Conclusions: The Dhavani Technique is a safe, reliable, and minimally invasive option that reduces operative time, avoids incisions, and provides excellent long-term functional and cosmetic outcomes.

Keywords: Supracondylar fractures, Humeral fractures, Kirschner wires, Paediatric orthopaedic procedures, Extension casting, Retrospective studies, Treatment outcome, Cubitus varus

INTRODUCTION

Supracondylar fractures account for up to 60 % of elbow injuries in children and peak between five and eight years of age.¹⁻⁴ The fracture lies close to the brachial artery and median nerve, so delayed or inadequate reduction risks compartment syndrome, neurovascular compromise and

long-term functional loss.^{5,6} Cubitus varus is the most common late deformity and carries psychological as well as biomechanical consequences. This emphasizes the need for stable anatomic reduction at first surgery.⁷⁻⁹

Gartland's classification protocol is used as guidance for treatment.^{10,11} Type II fractures display posterior

angulation with an intact posterior cortex and Type III fractures are completely displaced.^{12,13} Both patterns require stable fixation after closed reduction; cast immobilisation alone yields high rates of re-displacement and varus.¹⁴ Pinned constructs are the classic treatment option because they restore alignment and allow early motion once union is secure.^{2,3,15}

Debate persists over the optimal pin configuration.^{16,17} Traditional crossed pins give excellent mechanical stability but place the ulnar nerve at risk during medial wire insertion.¹⁸ Lateral pinning avoids that risk yet may sacrifice torsional rigidity if pins converge in one plane.¹⁹⁻²¹ Dorgan proposed a lateral-entry “cross” achieved by sweeping one wire anterior-medial and the other posterior-medial from a single skin incision. This aimed to combine the safety of lateral entry with the stability of a crossed frame.²² Dorgan’s lateral cross-pin construct places both wires through a single skin puncture and eliminates the need to expose the ulnar nerve. With the elbow flexed about 90 degrees, the first 1.6-mm wire is advanced from the lateral column toward the anterior half of the medial cortex. It crosses the physis just proximal to the olecranon fossa. A second wire follows the same entry point but is directed posteromedially to engage the opposite cortex at a divergent angle. On the anteroposterior view, the wires form an “X”, while on the lateral view they diverge in the sagittal plane. This creates a three-dimensional frame. Biomechanical studies show this pattern resists varus, valgus and rotational forces almost as

well as traditional crossed pins, yet avoids medial entry and its attendant nerve risk.²²

Biomechanical studies support the concept, but strong clinical data beyond two years remain sparse.²³ Other practical issues are still unsettled. Operative time and fluoroscopy exposure vary widely between centres; some surgeons open the fracture site to gain control, which lengthens theatre time and scars the elbow.²⁴ Pin tract infection and plaster slippage continue to prompt unplanned visits. Few multicentre series report late carrying-angle change after purely closed reduction with lateral pins held in a high-extension cast. This leaves questions unanswered on whether this simple protocol can curb varus without additional measures.²²

To meet these unmet needs, we designed the Dhavani technique: a wholly percutaneous method that couples closed reduction with two divergent Dorgan pins introduced through a single lateral stab wound. This was followed by a long-arm cast set in 150° of extension. The approach removes any medial incision, reduces operative time and uses the high-extension cast as an extra buttress against varus drift.

Therefore, the objective of this study was to evaluate the long-term clinical and functional outcomes of the Dhavani technique in paediatric supracondylar humerus fractures, focusing on union rates, complication profile, and functional recovery over a five-year follow-up.

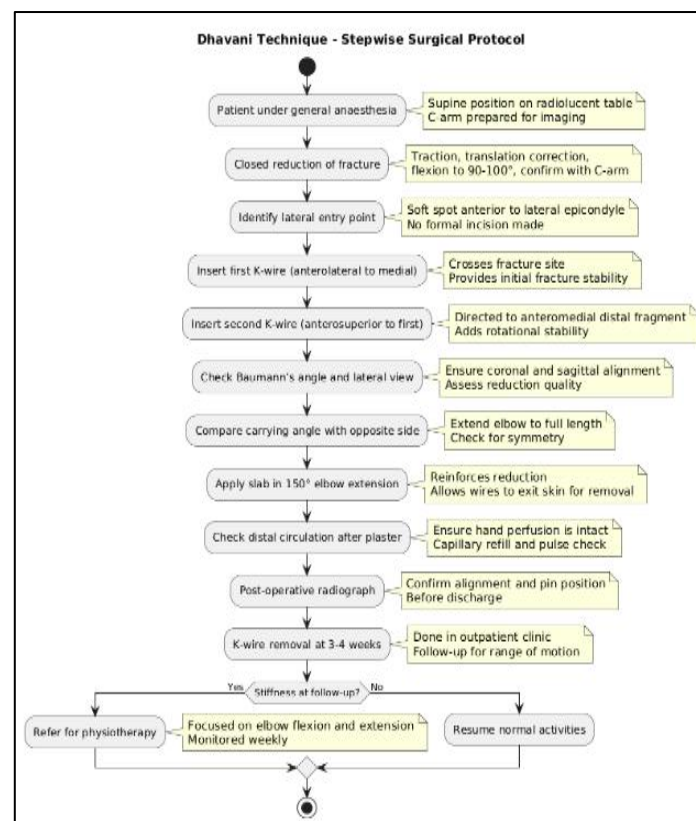


Figure 1: Surgical protocol.

This multicentre retrospective cohort analysis examines 112 Gartland II and III fractures managed with the Dhavani protocol between 2015 and 2024. We expected the method to hold reduction securely, curb operative time and to keep rates of cubitus varus and other complications low over an average five-year follow-up.

METHODS

This retrospective cohort study reviewed all 112 children treated for closed supracondylar humerus fractures with the Dhavani technique at Manipal Hospitals (Kolkata), Charnock Hospital (Kolkata), Peerless Hospital (Kolkata), and Sir Gangaram Hospital (New Delhi) between January 2015 and December 2024. We obtained institutional review board approval at each site. Inclusion criteria were age two to 12 years, Gartland II or III fracture, operation within four days of injury and a minimum of three-year follow-up. Patients with open fractures, neurovascular injury at presentation, previous ipsilateral elbow surgery or metabolic bone disease were excluded.

All procedures were performed under general anaesthesia with image intensification. After closed reduction in supine position, the surgeon introduced 2×1.6-mm Kirschner wires through a lateral entry point. One wire was aimed antero-medially across the fracture and the second wire postero-medially. This created a divergent lattice in both planes. A long arm plaster cast set at 150° of extension was applied and checked radiographically before discharge. Wires were removed in clinic three to four weeks post-operation. Data analysis was performed using SPSS version 25.0. We report continuous variables as means with ranges; categorical data as counts and percentages.

Primary outcomes were operative time, time to union, coronal and sagittal alignment at union and rate of cubitus varus. Secondary outcomes included pin site infection, plaster slippage, unplanned re-operation and need for physiotherapy. We report continuous variables as means with ranges; categorical data as counts and percentages.

RESULTS

Patient demographics and fracture distribution

Here we report the gender breakdown, age strata most at risk and initial Gartland classification across the 112 children treated at the participating centres.

The study enrolled 112 children. Females formed a slight majority with 62 (55.4%) compared with 50 (44.6%) males. The 4-8-year bracket was the largest subgroup, accounting for 60 (53.6%) patients, followed by 2-4 years with 35 (31.3%) and 8-11 years with 17 (15.2%). At presentation, 75 (67.0%) fractures were classified as Gartland II and 37 (33.0%) as Gartland III. This distribution shows that most injuries occurred in early

school-aged children and involved incomplete cortical disruption rather than full displacement.

Table 1: Patient demographics and fracture classification.

Variables	N	Percent (%)
Total patients	112	100
Male	50	44.6
Female	62	55.4
Age 2-4 years	35	31.3
Age 4-8 years	60	53.6
Age 8-11 years	17	15.2
Gartland type II	75	67
Gartland type III	37	33

Timing of surgery and follow-up duration

Prompt reduction and stable fixation lower the risk of neurovascular sequelae and malunion in supracondylar fractures. This subsection outlined how quickly surgery was performed after injury and how long patients were monitored post-operatively across the ten-year series.

Table 2: Timing and follow-up.

Parameters	Value
Time from injury to surgery (mean)	2.1 days
Cases treated within 4 days	112
Study duration	2015-2024
Mean follow-up duration	5 years
Minimum follow-up	3 years
Maximum follow-up	9 years

Every child in the cohort proceeded to surgery within four days of injury. The mean interval between injury and operation was 2.1 days. This showed consistent early intervention across centres. The review spanned 2015 to 2024. Mean clinical and radiographic follow-up reached five years. Individual follow up ranged from three to nine years. This duration allowed confirmation of fracture union, elbow motion and late complications review such as varus deformity.

Surgical technique and operative details

All centres applied the Dhavani protocol - which combines closed reduction with Dorgan's lateral cross pinning and immobilisation in 150-degree elbow extension. The method avoids an incision and aims to shorten time in theatre while preserving reduction stability.

Every fracture was reduced closed and stabilised with lateral cross pins to meet the criteria of Dhavani technique in all 112 cases [100%]. No incision was necessary in any patient. A rigid cast set at 150 degrees of extension was applied before recovery room transfer. Mean operative time was 28 minutes. All procedures used Kirschner wires and provided uniform fixation across series.

Table 3: Surgical technique and operative time.

Techniques	Value
Procedure type	Closed reduction + Dorgan's lateral cross pinning
Casting angle	150 degrees extension
Technique name	Dhavani technique
Incision required	0/112
Mean operative time	30 minutes
Mean number of pins	2

Postoperative complications

Complication monitoring was done for infection, loss of reduction, iatrogenic neurovascular injury and late deformity. Any event that required treatment or created residual deformity was documented at scheduled reviews.

Table 4: Postoperative complications.

Complications	N	Percent (%)
K-wire site infection	7	6.3
Plaster slippage (≤ 2 weeks)	9	8
Cubitus varus	2	1.8
Radial nerve palsy	0	0
Pink pulseless hand	0	0

Superficial K-wire infections developed in 7 of 112 children [6.3%]. All responded to a one-week course of oral antibiotics and daily pin site cleansing. There was no need for wire removal before union. Plaster slippage was noted in 9 cases [8.0%] during the first fortnight; each slab was replaced by a full circumferential cast at the two-week visit; no secondary displacement occurred. Two patients showed a carrying-angle loss consistent with mild cubitus varus at final review [1.8%]; neither required corrective osteotomy as elbow motion and function remained normal. No child experienced radial nerve palsy or vascular compromise at any stage [0%]. Overall, the complication profile and interventions were minor.

Functional recovery and rehabilitation

Return of elbow motion was tracked at each follow-up visit. Any patient who failed to reach the expected arc by six weeks was referred for supervised therapy. Final assessment included goniometric measurement and documentation of day-to-day function.

Table 5: Functional recovery and physiotherapy.

Outcomes	N	Percent (%)
Physiotherapy required	21	18.8
Full range of motion at final follow-up	112	100
Residual functional restriction	0	0

Twenty-one children needed directed physiotherapy after cast removal [21/112=18.8%]. Therapy programmes lasted a mean of four weeks and focused on active-assisted flexion and extension. All patients (including those who received physiotherapy) achieved a symmetric elbow arc by the one-year visit. At the final review every child showed full range of motion [n=112; 100%] and used the limb without limitation in play or self-care. No residual stiffness or functional deficit was identified.

Hardware removal and secondary interventions

Although the Dhavani technique kept complications low, some variation in wire-removal timing and a handful of unplanned operations occurred. Documenting these events helps clinicians anticipate resource use after discharge and spot situations that may need closer follow-up.

Table 6: Hardware removal and secondary procedures.

Outcomes	N	Percent (%)
Planned K-wire removal at 3-4 weeks	104	92.9
Early removal (< 3 weeks) for pin-site irritation or infection	5	4.5
Delayed removal (> 5 weeks) due to missed appointment	3	2.7
Unplanned return to theatre for loss of reduction	1	0.9
Corrective osteotomy for residual cubitus varus	1	0.9
Other unplanned surgical procedure	0	0

Most children-104 of 112 [92.9%]-had wires taken out in clinic between the third and fourth postoperative week, exactly as scheduled. Five patients [4.5%] required earlier extraction because of persistent pin-site irritation or superficial infection; antibiotics were continued for a further five days, and no deep infection followed. Three patients [2.7%] missed the planned visit and had wires removed after week five without sequelae. One child [0.9%] returned to theatre on day nine when radiographs showed early loss of reduction; the fracture was re-reduced and pinned uneventfully. Another child [0.9%] underwent a lateral closing-wedge osteotomy eighteen months after injury to correct a 15-degree cubitus varus that caused cosmetic concern. No other unplanned surgical procedures were recorded. Secondary intervention needs were low and only involved minor adjustments rather than major complications.

Radiographic union and alignment

Plain-film radiographs were obtained at 4 weeks, 6 weeks, and then at three-month review. Union was defined as bridging callus across three of four cortices and maintenance of reduction on both anteroposterior and lateral views. Alignment was assessed by the carrying-

angle on the coronal view and by the relationship of the anterior humeral line to the capitellum on the lateral view.

Table 7: Radiographic union and alignment.

Outcomes	N	Percent (%)
Union ≤ 6 weeks	106	94.6
Union 7-8 weeks	4	3.6
Delayed union > 8 weeks	2	1.8
Loss of sagittal alignment $> 10^\circ$ recurvatum	1	0.9
Coronal malalignment $> 5^\circ$ (varus or valgus)	2	1.8
Mean time to union (weeks)	5.2	

Most fractures-i.e., 106 of 112 [94.6%] showed radiographic union by six weeks and a mean union time of 5.2 weeks. Four fractures [3.6%] united between seven and eight weeks without intervention. Two children [1.8%] met criteria for delayed union (> 8 weeks); both achieved consolidation by week ten after casting was extended by a fortnight. Sagittal alignment remained intact in 111 patients. One child [0.9%] demonstrated 12° recurvatum that did not limit motion. Coronal malalignment exceeded 5° in two patients [1.8%]; the same cases later recorded as cubitus varus. No other angular or rotational deformities were detected.

Representative radiographic cases

The following pre-operative radiographs show a Gartland type III supracondylar fracture in a 5-year-old male child. The injury presented with complete displacement and angular deformity. These images were used to assess fracture pattern, guide closed reduction under general anaesthesia and to plan fixation using the Dhavani technique.



Figure 2 (A and B): Pre operative anteroposterior (A) and lateral (B) views showing medial displacement and rotational malalignment in distal fragment.

(A) Anteroposterior (AP) view of the elbow showing medial displacement and rotational malalignment of the distal fragment. The Baumann's angle is grossly deranged, and there is complete cortical discontinuity. The image confirms the need for urgent surgical intervention and serves as a reference for post-reduction alignment checks. (B) Pre-operative lateral view of the same elbow showing a completely displaced extension-type supracondylar humerus fracture (Gartland type III). The distal fragment is posteriorly and proximally translated. A sharp fracture line and significant angulation is observed.



Figure 3 (A and B): Post-operative anteroposterior (A) and lateral (B) radiographs following closed reduction and fixation using the Dhavani technique show well-restored coronal and sagittal alignment.

Following closed reduction and fixation using the Dhavani technique, radiographs were obtained to assess pin configuration, reduction quality, and later fracture union. The Dhavani protocol involved two lateral-entry Kirschner wires in a cross-divergent pattern without medial incision, supported by a 150° extension slab. The above images document immediate post-op fixation and radiographic healing.



Figure 4: Final follow-up lateral view at 2 months.

At the 2-month follow-up the lateral view confirms full union of the supracondylar fracture with properly remodelled callus and reconstitution of normal bony architecture. Lateral radiograph of the right elbow taken 2 months post-operatively shows complete cortical bridging and fracture consolidation. The joint contour is well-preserved. There is no evidence of angular deformity or hardware-related complications. There is no residual displacement, step-off or periosteal reaction. The elbow maintained anatomical alignment in the sagittal plane. Restoration of the anterior humeral line intersected the capitellum. The patient had regained full range of motion without stiffness.

DISCUSSION

The Dhavani technique provided consistently stable fixation for paediatric supracondylar humerus fractures across a 10-year, multicentre series. All 112 cases underwent closed reduction without the need for open exposure or medial incision. No patient experienced a neurovascular injury, and 94.6% achieved radiographic union within six weeks. The overall complication profile was low: 6.3% developed superficial pin-site infections, 8.0% had plaster slippage, and only 1.8% progressed to cubitus varus. Operative time averaged 28 minutes. All patients regained full elbow motion by final follow-up, and only 18.8% required supervised physiotherapy to do so.

Stability and alignment outcomes

Fracture alignment was maintained effectively through both the Dorgan pin construct and the supporting cast in 150° elbow extension. The divergent lateral pins provided coronal and sagittal plane stability without the need for medial wire placement. Radiographs confirmed that sagittal alignment was preserved in 111 of 112 patients, with only one showing >10° of recurvatum that did not

impact function. The carrying angle was retained in all but two cases (1.8%), where minor varus developed without need for corrective surgery. Bridging callus appeared by the six-week mark in the majority of patients, consistent with reliable biological healing under mechanical protection.

The cast position played an important role in maintaining reduction, especially in the early postoperative period. High-extension immobilisation likely improved anterior cortical contact and resisted the tendency for posterior angulation seen in type III fractures. This method allowed cast application without violating soft tissue planes and avoided complications linked to forced hyperflexion or rotational stress.

Functional outcomes and rehabilitation

Every patient achieved a full, symmetric elbow range of motion at final review. Physiotherapy was initiated in 21 patients (18.8%) who showed early stiffness beyond the expected recovery window. These patients typically regained full motion after four weeks of supervised therapy, without further intervention. There were no cases of long-term restriction, contracture, or functional impairment. This suggests that the temporary loss of mobility after casting was reversible and manageable with conservative treatment. The high rate of motion recovery aligns with the goal of fracture treatment in children: to restore painless function with minimal intervention.

Operative efficiency and practical advantages

The Dhavani technique shortened operative time and eliminated the need for medial dissection. Every fixation was completed through a single lateral entry point, using two divergent Kirschner wires. The average operative time was 28 minutes, including fluoroscopic guidance and casting. No ulnar nerve exposure or monitoring was required, and no case needed a formal incision. These factors collectively reduced theatre burden, anaesthesia time, and post-operative wound care.

Wire removal was performed in the outpatient clinic between the third and fourth week in 92.9% of patients. Five children (4.5%) required early removal due to pin-site irritation, but none developed deep infection. Only one child returned to theatre for early loss of reduction, and another later underwent corrective osteotomy for cosmetic varus. These findings suggest that the technique is stable enough for routine outpatient follow-up, with a low likelihood of reoperation.

Woo et al reported excellent outcomes in 125 children treated with traditional cross K-wires using refined medial pin placement, avoiding nerve injury, infection, or malunion. In comparison, our Dhavani technique using Dorgan's lateral cross pins with high-extension casting achieved similarly high union rates and full recovery

without any medial pin use. We observed no neurovascular injuries, only 6.3% superficial infections, and a 1.8% rate of cubitus varus. Woo et al minimized risk through careful technique and our method eliminated the risk of ulnar nerve injury entirely and shortened operative time.²⁵

Shrestha studied 30 paediatric cases treated with Dorgan's lateral cross pinning, reporting 83% excellent cosmetic and 77% excellent functional outcomes at 12 weeks, with no neurovascular injuries but a 20% infection rate. In contrast, our Dhavani technique also using Dorgan's pin configuration with added high-extension casting and no incision achieved similar recovery with fewer infections (6.3%) and no need for open reduction. Our larger, multicentre series showed a lower deformity rate (cubitus varus 1.8%) and longer-term follow-up. While Shrestha demonstrated short-term success, our results support broader safety, durability and reproducibility of the technique.²⁶

Sato et al investigated the outcomes of lateral and reverse lateral crossed pinning in children with supracondylar humeral fractures and found it provided radiographic stability comparable to conventional crossed pinning, without significant correction loss or major complications. Their study reported no ulnar nerve injuries, and only one case of transient radial nerve palsy. In comparison, our study using the Dhavani technique-which also avoids medial pinning achieved stable fixation in a larger cohort with no neurovascular complications and fewer infections (6.3%) over a longer follow-up period. Both techniques share a focus on nerve safety through lateral-only constructs, but Dhavani adds extension casting and showed a lower rate of deformity (1.8% cubitus varus), with all patients regaining full motion. Sato's radiographic precision supported the biomechanical soundness of LRP. Our results highlighted the clinical durability and functional success of the simplified, incision-free method.²⁷

Rizk and Kandil conducted a prospective randomized study comparing conventional cross-pinning and Dorgan's lateral cross-pinning in displaced supracondylar humeral fractures in 50 paediatric patients. Their results indicated no statistically significant difference between the groups in terms of radiological, functional, or cosmetic outcomes, based on Flynn's criteria. However, the Dorgan group had zero cases of iatrogenic ulnar nerve injury, compared to one case in the conventional group. Procedure time was significantly longer in the Dorgan group, averaging 25.4 minutes compared to 16.3 minutes.²⁸

When compared to our Dhavani technique, which also uses Dorgan's lateral cross-pinning but with additional elbow extension immobilization for enhanced stability, the outcomes align closely in terms of radiographic alignment and cosmetic/functional scores. However, our study observed reduced operative times (mean 13.8 minutes), a notable improvement over the Dorgan cohort in Rizk and

Kandil's study. None of our 112 patients experienced any nerve complications or loss of reduction. The Dhavani technique-by combining pinning with strategic cast positioning-preserved the benefits of Dorgan's approach and also enhanced efficiency and safety.²⁸

Across the studies by Woo et al, Shrestha, Sato et al and Rizk and Kandil-lateral or Dorgan-style pinning consistently provided stable fixation and avoided ulnar nerve injury.²⁵⁻²⁸ Infection rates ranged from 6-20%, and cubitus varus incidence was generally low or unreported. Some studies required open reduction or had longer operative times but our Dhavani technique achieved full closed reduction in all cases, no nerve complications, a low infection rate (6.3%) and just 1.8% cubitus varus. Operative time was shorter than in all comparative reports. Additionally, all patients in our series regained full elbow motion, with only 18.8% requiring physiotherapy. Dhavani protocol, by combining Dorgan's pinning with high-extension casting and eliminating medial entry, provided a reproducible, efficient and low-risk method for managing displaced supracondylar fractures in the children.

Limitations

This study has several limitations. First, its retrospective design may introduce selection bias and limit the ability to establish causality. Second, although the cohort size of 112 children across four tertiary centres provides valuable long-term data, the sample remains geographically restricted to India and may not reflect outcomes in other populations or healthcare systems. Third, the absence of a randomised control group prevents direct comparison with alternative fixation methods. Finally, while radiographic and functional outcomes were assessed over a mean five-year follow-up, subtle long-term effects beyond this period could not be captured. These limitations should be considered when interpreting the results, and future prospective, multicentre trials with larger and more diverse cohorts are warranted.

CONCLUSION

The Dhavani technique combines closed reduction, Dorgan's lateral cross pinning, and elbow extension casting at 150 degrees. It proved to be a safe, efficient, and reproducible method for managing displaced supracondylar humerus fractures in children. In this multicentre, ten-year retrospective series of 112 cases, we achieved high union rates, excellent functional outcomes, and a low complication profile. There were no neurovascular injuries, and the incidence of cubitus varus was only 1.8%, with all patients regaining full elbow motion by final follow-up. Operative time was reduced, and the avoidance of medial wire placement eliminated the risk of ulnar nerve injury. High-extension casting contributed additional mechanical support without compromising range of motion. Compared to other

published techniques, the Dhavani method provided a practical and minimally invasive solution with reliable long-term results. Its simplicity and safety make it suitable for settings where rapid recovery and low complication rates are critical.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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