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ORIGINAL ARTICLE

Advanced volar locking plate fixation for intra and extra-articular distal radius fractures: a retrospective study

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ABSTRACT

Aim Distal radius fractures are among the most common orthopaedic injuries, with a high risk of functional impairment. Volar locking plates have become the standard treatment for unstable and extra-articular fractures, offering excellent outcomes compared to traditional techniques. This study aimed to evaluate clinical, radiographic, and functional outcomes of volar locking plate fixation in patients with intra- and extra-articular distal radius fractures.

Methods A retrospective analysis was conducted on 34 patients treated with volar locking plates between 2018 and 2024. Outcomes were assessed using the Disabilities of the Arm, Shoulder and Hand (DASH) score, Visual Analog Scale (VAS) for pain, range of motion, and radiographic consolidation. Complications were recorded and analysed.

Results At a mean follow-up of 24 months, the mean DASH score was 4.2±1.8 and VAS score was 0 in all cases. Range of motion (ROM) recovery ranged from 93% to 98% of the contralateral side. Radiographs confirmed complete healing in all patients. Only two experienced minor soft tissue discomfort.

Conclusion Volar locking plate fixation for distal radius fractures ensures excellent functional recovery, reliable bone healing, and minimal complications, making it a safe and effective treatment approach.

Keywords: bone plates, orthopaedic procedures, range of motion, articular, retrospective studies, treatment outcome

INTRODUCTION

Distal radius fractures represent approximately 15% of all extremity fractures and affect a wide age range (1). These injuries are particularly common in elderly patients due to osteoporotic bone and low-energy trauma, while younger individuals typically sustain them from high-energy mechanisms such as motor vehicle accidents or sports injuries (2). If not adequately treated, these fractures may lead to chronic pain, stiffness, reduced range of motion, and long-term disability (3).

Over the past two decades, surgical management has evolved considerably. Traditional methods such as cast immobilization and external fixation often failed to ensure anatomical reduction and stable fixation, resulting in malunion and suboptimal functional outcomes (4). Volar locking plates have since emerged as the gold standard for managing complex distal radius fractures, combining rigid internal fixation with the potential for early mobilization (5,6). Their anatomical, low-profile design reduces soft tissue irritation, particularly involving the flexor and extensor tendons (7), and provides biomechanical stability to restore radial height, inclination, and volar tilt (8). Despite these benefits, complications such as tendon injuries, hardware irritation, and infection still occur, with rates reported between 22% and 27% (9). Nonoperative treatment remains a reasonable alternative in selected elderly patients with low-risk fracture patterns (10). Another critical aspect is the distinction between extra-articular and intra-articular fractures: the former are typically more amenable to surgical fixation due to their simpler morphology, while the latter present greater challenges in restoring joint congruence and alignment (11). Recent studies advocate for individualized treatment based on fracture classification, patient characteristics, and functional goals (12–16).

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This study aims to evaluate clinical, radiographic, and functional outcomes of volar locking plate fixation in patients with both extra-articular and intra-articular distal radius fractures, contributing to current evidence on the effectiveness and safety of this surgical approach.

PATIENTS AND METHODS

Patients and study design

This retrospective study evaluated the clinical, radiographic, and functional outcomes of 34 patients treated for intra- and extra-articular distal radius fractures using the GEMES GR distal volar locking plate system. Surgical procedures were performed at the Giaccone University Hospital, Palermo, between 2018 and 2024 by experienced orthopaedic surgeons, with contributions from a multidisciplinary team involved in clinical follow-up, data analysis, and manuscript preparation. All patients provided an informed consent for the use of their anonymized clinical data.

The cohort included 18 males and 16 females, with a mean age of 58 years (range: 20–80 years).

Fractures were classified according to the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) system (1): 20 extra-articular fractures (types A2.2 and A3.1) and 14 intra-articular fractures (types C2.1 and C3.2). Fifteen fractures involved the left wrist and nineteen the right wrist. Plate selection was based on fracture morphology and patient anatomy: 12 small, 20 medium, and 2 large GEMES GR distal volar locking plate system plates were implanted (Table 1).

Inclusion criteria were: patients aged 18 years or older, diagnosed with intra- or extra-articular distal radius fractures, treated with the GEMES GR distal volar locking plate system, and followed clinically and radiographically for a minimum of 12 months. Exclusion criteria included polytrauma, pathological or open fractures classified as Gustilo–Anderson grade II or higher (the Gustilo–Anderson classification categorizes open fractures based on wound size, level of contamination, and soft-tissue damage).

Table 1. Patient demographics and fracture details

Patient ID	Age (years)	Sex	AO fracture*	Fracture type
P01	45	Male	A2.2	Extra-articular
P02	32	Male	C3.2	Intra-articular
P03	60	Male	A3.1	Extra-articular
P04	54	Male	C2.1	Intra-articular
P05	27	Male	A3.1	Extra-articular
P06	78	Male	A3.1	Extra-articular
P07	39	Male	C3.2	Intra-articular
P08	58	Male	A2.2	Extra-articular
P09	68	Male	A3.1	Extra-articular
P10	50	Male	C2.1	Intra-articular
P11	44	Male	A2.2	Extra-articular
P12	61	Male	C3.2	Intra-articular
P13	70	Male	A3.1	Extra-articular
P14	38	Male	A2.2	Extra-articular
P15	52	Male	C2.1	Intra-articular
P16	29	Male	C3.2	Intra-articular
P17	47	Male	A2.2	Extra-articular
P18	64	Male	A3.1	Extra-articular
P19	36	Male	C3.2	Intra-articular
P20	41	Female	A2.2	Extra-articular
P21	55	Female	C2.1	Intra-articular
P22	62	Female	A3.1	Extra-articular
P23	38	Female	A2.2	Extra-articular
P24	75	Female	C3.2	Intra-articular
P25	48	Female	A2.2	Extra-articular
P26	67	Female	C2.1	Intra-articular
P27	72	Female	A3.1	Extra-articular
P28	58	Female	A2.2	Extra-articular
P29	46	Female	C3.2	Intra-articular
P30	31	Female	A3.1	Extra-articular
P31	40	Female	A2.2	Extra-articular
P32	69	Female	C2.1	Intra-articular
P33	59	Female	A3.1	Extra-articular
P34	49	Female	A2.2	Extra-articular

* Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) system

Methods

All procedures followed a standardized surgical protocol. Under axillary block or general anaesthesia, patients were positioned supine with the injured limb supported on a radiolucent hand table. A volar Henry approach (5,6) was used to expose the fracture site. Fractures were reduced under fluoroscopic control, and the appropriate plate size was selected and fixed with locking screws to restore alignment and stability. Final intraoperative fluoroscopy confirmed fracture reduction and implant positioning.

Postoperative management included wrist immobilization with a splint for two weeks. Passive mobilization was initiated after suture removal, followed by active range-of-motion exercises at four weeks and strengthening at six weeks. Follow-up visits were scheduled at 2 weeks, 6 weeks, 3 months, 6 months, and 12 months, with annual assessments thereafter.

Primary outcomes included: pain, measured by the Visual Analog Scale (VAS) (4), functional recovery, assessed using the Disabilities of the Arm, Shoulder, and Hand (DASH) (5) score, range of motion (ROM) (6) in flexion, extension, pronation, and supination.

Visual Analog Scale (VAS): The VAS is a validated 10-point scale used to quantify pain intensity, where 0 indicates no pain and 10 represents the worst imaginable pain. Patients mark their perceived pain level on a 10-cm line, providing a continuous and sensitive measure of postoperative pain.

The Disabilities of the Arm, Shoulder and Hand (DASH) (5) is a 30-item, patient-reported outcome measure evaluating upper-limb disability and symptoms. Each item was scored from 1 (no difficulty) to 5 (unable to perform), generating a final score ranging from 0 to 100, where: 0 = no disability, 100 = maximum disability. The DASH is widely used to assess functional recovery after wrist and upper-extremity injuries.

Radiographic evaluation focused on fracture consolidation, radial height, inclination, and volar tilt. All complications, including tendon irritation, hardware prominence, infection, malunion, and nonunion, were systematically recorded throughout follow-up.

RESULTS

A total of 34 patients with distal radius fracture were treated with volar locking plate fixation and followed for a mean pe-

riod of 24 months (range: 12–36 months). The study population included both extra-articular and intra-articular fracture types, classified according to the AO/OTA system: 20 extra-articular fractures (A2.2 and A3.1) and 14 intra-articular fractures (C2.1 and C3.2).

Fifteen fractures involved the left wrist and nineteen the right. Plate selection was based on fracture morphology and patient anatomy: 12 patients received small plates, 20 medium plates, and 2 large plates (Table 2).

Table 2. Patient demographics and procedural details

Category	Count
Total number of patients	34
Fracture side (left wrist)	15
Fracture side (right wrist)	19
Extra-articular fractures	20
Intra-articular fractures	14
Plate size (small)	12
Plate size (medium)	20
Plate size (large)	2

Pain outcomes were excellent: at final follow-up, all patients reported complete pain resolution. Functional evaluation using the DASH score showed minimal residual disability, with a mean final score of 4.2±1.8. Range of motion (ROM) measurements demonstrated near-complete restoration of wrist function, with mean flexion, extension, pronation, and supination values ranging from 70° to 85°, corresponding to 92–98% of the contralateral wrist's mobility (Table 3).

Table 3. Detailed Range of Motion (ROM) outcomes following volar locking plate fixation for distal radius fractures, including mean final joint angles and percentage recovery compared to the contralateral limb

ROM measurement	Mean final ROM (degrees)	Compared to contralateral (%)
Flexion	75	95%
Extension	70	93%
Pronation	85	97%
Supination	85	98%

Radiographic analysis confirmed complete fracture healing in all cases, with evidence of bridging callus and no instances of delayed union, malunion, or nonunion. Anatomical parameters including radial height, radial inclination, and volar tilt were successfully restored and maintained throughout the follow-up period (Figures 1 and 2).

No intraoperative complications such as reduction difficulties or hardware malposition were observed.

Postoperatively, no flexor tendon problems, infections, or hardware irritation occurred.

Only two patients (5.8%) reported transient soft-tissue discomfort, which was resolved with conservative measures. There were no cases of malunion, nonunion, delayed union, tendon irritation, or hardware-related problems throughout the follow-up.

These results confirm that volar locking plate fixation is a safe and effective technique for treating both extra-articular and intra-articular distal radius fractures. The combination of complete pain relief, excellent functional recovery, and favourable radiographic outcomes supports the clinical reliability of this surgical approach across different fracture types.

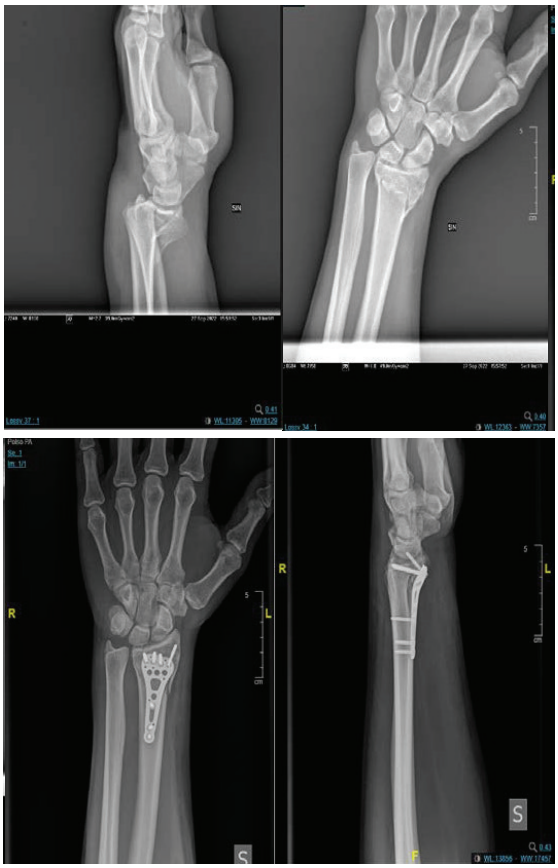

Figure 1. Radiographic progression of a distal radius fracture managed with volar locking plate fixation. A-B) Preoperative anteroposterior and lateral wrist radiographs showing an extra-articular distal radius fracture with loss of volar tilt and mild radial shortening; C-D) Postoperative anteroposterior and lateral radiographs demonstrating anatomic reduction of the fracture and stable internal fixation using a volar locking plate. Restoration of volar tilt, radial height, and inclination is clearly visible. No hardware malposition or screw penetration into the dorsal compartments is observed (Policlinico Universitario Giaccone, Palermo; 2024)

DISCUSSION

Distal radius fractures are among the most frequent injuries encountered in orthopaedic practice, representing a considerable clinical and economic burden. These fractures predominantly affect two patient groups: elderly individuals with osteoporotic bone who typically sustain low-energy injuries, such as falls, and younger patients involved in high-energy trauma, including motor vehicle accidents and sports-related incidents (1,2). The rising incidence, particularly within the aging population, highlights the need for effective treatment strategies to restore wrist function and minimize complications (3). Inadequate management of distal radius fractures may result in substantial morbidity, including malunion, joint stiffness, diminished grip strength, and chronic pain (17). These complications not only impair wrist function but also significantly affect patients' overall quality of life. Consequently, advances in surgical techniques and implant design have become essential for improving clinical outcomes.

Over the past two decades, volar locking plates have emerged as the gold standard for the treatment of complex and unstable distal radius fractures (18). Compared with traditional approaches such as casting or external fixation, volar locking

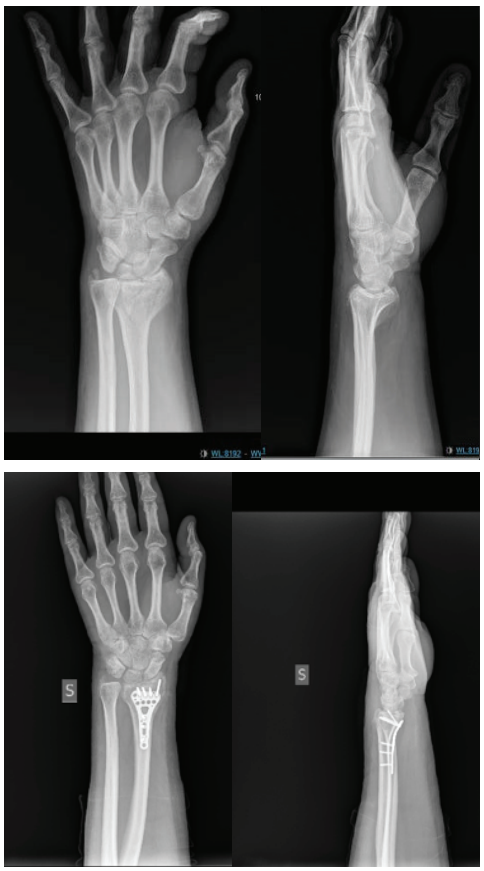

Figure 2. Radiographic sequence of a patient with a distal radius fracture treated with volar locking plate fixation. A-B) Preoperative anteroposterior and lateral wrist radiographs demonstrate an extra-articular distal radius fracture characterized by dorsal displacement, loss of volar tilt, and mild radial shortening; C-D) Postoperative anteroposterior and lateral radiographs show anatomic restoration of radial height, inclination, and volar tilt following internal fixation using a volar locking plate. The implant is correctly positioned, with no evidence of screw protrusion into the dorsal compartments or postoperative complications (Policlinico Universitario Giaccone, Palermo; 2024)

plates provide several key advantages, including stable internal fixation, precise anatomical reduction, and the possibility for early mobilization (5,18). These features collectively contribute to superior functional and radiographic outcomes, as supported by numerous clinical studies (8,19). Modern volar locking plates incorporate low-profile designs and anatomical contouring, significantly reducing soft-tissue complications—particularly flexor tendon irritation, extensor tendon attrition, and hardware prominence—that were common with earlier-generation implants (20).

The present study evaluated the GEMES GR distal volar locking plate system within this context. Although the detailed results are reported elsewhere in the manuscript, the findings were consistent with existing literature supporting the effectiveness of volar locking plates in ensuring stable fixation, reducing pain, and promoting early functional recovery (18,19). The low-profile configuration and anatomical design of the GEMES GR plate appear to have contributed to a reduced incidence of soft-tissue complications, improving both comfort and wrist mobility during rehabilitation (20). Moreover, the system's ability to restore anatomical alignment while minimizing soft-tissue disruption likely supports accelerated healing and optimized functional recovery (20).

Literature comparisons reinforce these observations. Diaz-Garcia and Chung (2012) demonstrated superior functional outcomes for volar plating relative to external fixation and casting, with notable improvements in pain scores and DASH outcomes (18). Similarly, Clement et al. (2013) reported faster recovery and fewer complications in patients treated with volar plates compared with traditional fixation methods (19). Mulders et al. (2018) found favourable range-of-motion outcomes, attributing these results to the mechanical stability provided by modern plate designs, which permit early mobilization and reduce postoperative stiffness (8).

The absence of complications such as flexor tendon irritation (particularly of the flexor pollicis longus), extensor tendon tenosynovitis or rupture (e.g., extensor pollicis longus), hardware prominence, infection, and symptomatic screw protrusion in the present study underscores the improved design characteristics of the GEMES GR system. Historically, such complications were frequently reported with older, bulkier volar plate models that lacked adequate contouring, had sharp edges, or required dorsal screw lengths with a higher risk of penetrating the extensor compartments (17–25). By minimizing these risks, the GEMES GR plate appears to enhance patient outcomes, particularly regarding wrist mobility and functional recovery.

Future research should include larger and multicentre cohorts to validate the present findings more comprehensively. Comparative studies evaluating the GEMES GR system against other modern volar locking plate designs may further clarify its clinical advantages. Additionally, long-term follow-up studies are needed to assess the durability of functional and radiographic outcomes over extended periods of time. Incorporating patient-reported outcome measures (PROMs) would provide valuable insight into subjective satisfaction and quality-of-life improvements. Finally, economic evaluations examining the cost-effectiveness of the GEMES GR distal volar locking plate system relative to alternative implants could inform clinical decision-making within value-based healthcare models.

In conclusion, this study affirms the GEMES GR distal volar locking plate system as a highly effective solution for managing intra and extra-articular distal radius fractures. The system's advanced design, characterized by its low-profile, anatomical contouring, and robust locking mechanism, successfully addresses the limitations of previous implant generations, yielding superior clinical outcomes with minimal complications. Thus, the GEMES GR distal volar locking plate system represents a significant advancement in fracture management, facilitating improved functional recovery and patient satisfaction.

Author Contributions Statement:

G.R., F.B., E.S and G.V.: conception, methodology, writing; A.P. and F.G.: software, validation; F.L and A.S.: investigation; F.D.M and A.Z.: resources; G.T., A.Z, L.C. and G.R.: data curation, consent for pf-visualization; G.R., GT, : supervision; L.C.: writing—review and editing. All authors have read and agreed to the published version of the manuscript.

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TRANSPARENCY DECLARATION

Conflict of interests: None to declare**.**

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