International Journal of Science and Healthcare Research
[Indexed, Peer-Reviewed Journal]
Vol. 11; Issue: 2; April-June 2026
Website: ijshr.com
ISSN: 2455-7587

Case Study

Static Progressive Orthotic Intervention for Arthrofibrosis Following Internal Fixation of Elbow Medial Condyle and Capitellum Fractures

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DOI: https://doi.org/10.52403/ijshr.20260205

ABSTRACT

This clinical case study examined the orthotic management of post-traumatic elbow stiffness in a 15-year-old male following a right medial condyle fracture and comminuted capitellum fracture. Despite successful surgical stabilization via open reduction internal fixation, the subject presented with significant arthrofibrosis, restricted passive range of motion limited to 110 degrees, and secondary finger flexion stiffness.

The intervention focused on the application of a turnbuckle-type static progressive elbow splint that integrated the wrist and hand. The scope of the treatment involved utilizing a static progressive stretching mechanism to apply low-load, prolonged tension to the periarticular tissues. This approach aimed to facilitate stress relaxation and maintain the range of motion gains achieved during manual physiotherapy sessions. The inclusion of the distal joints addressed the extrinsic flexor length-tension relationship to prevent permanent claw-like resting postures.

Findings indicated that the turnbuckle design provided a controllable, non-elastic force that was well-tolerated by the adolescent patient, which enhanced treatment compliance and allowed for measurable progress tracking. The multi-joint orthotic approach effectively addressed both the primary injury site and secondary distal complications. In conclusion, the integration of static progressive orthoses into post-surgical protocols proved to be an effective evidence-based strategy for transitioning restricted joints toward functional range of motion.

Keywords: Post-traumatic elbow stiffness, Static progressive orthoses, Turnbuckle splint, Arthrofibrosis, Stress relaxation

INTRODUCTION

Functional independence relies heavily on the ability to move the elbow without discomfort, as this mobility allows for the precise positioning of the hand during daily tasks. When the joint suffers a significant injury, a series of biological responses can trigger a decline in flexibility. This resulting condition, known as arthrofibrosis, creates physical barriers that negatively impact an individual's lifestyle and autonomy. [1]

Morrey categorized this stiffness into three types: intrinsic, extrinsic, or a combination of both. Intrinsic stiffness stems from internal joint issues such as articular surface irregularities, the development of osteophytes, or intra-articular scarring. Extrinsic stiffness is caused by external factors like the tightening of the joint capsule, hardware interference, or heterotopic ossification. In clinical practice, most patients present with a "mixed" etiology. While our knowledge of the pathogenesis behind this condition is growing, it remains partially understood. Although the exact frequency of post-traumatic stiffness is not fully documented, research suggests it is directly correlated with the severity of the initial injury and the length of the immobilization period. [1]

Most daily tasks can be successfully completed within a functional "window" of 100 degrees, specifically ranging from 30 degrees of extension to 130 degrees of flexion, alongside 100 degrees of forearm rotation. Consequently, the primary objective of rehabilitation is to restore this functional arc, even if a full anatomical range is not achievable. Treatment strategies vary in complexity and invasiveness, beginning with conservative measures such as specialized physiotherapy, orthotic bracing, and joint manipulation. When non-surgical methods are insufficient, operative arthrolysis performed through either open or arthroscopic techniques may be required. [1]

Despite their utility, traditional rehabilitation techniques are often hindered by lengthy treatment durations, a heavy dependence on clinical staff, and a lack of robust scientific validation. Furthermore, elastic or dynamic bracing systems frequently trigger inflammation or skin irritation due to the unrelenting pressure applied to the limb, often causing patients to discontinue use. In contemporary practice, static progressive devices have emerged as a preferred alternative for managing severe joint rigidity following traumatic events or surgical procedures. These tools function through the mechanical principles of stress relaxation and tissue creep, with research indicating that stress relaxation allows for more rapid tissue lengthening. [2]

This clinical report evaluates the orthotic treatment of a fifteen-year-old male suffering from restricted elbow mobility following surgical repair of a right-sided medial condyle and fragmented capitellum fracture. The patient was managed with a custom-engineered static progressive device incorporating a turnbuckle assembly at elbow with wrist and finger extension to prevent wrist and finger flexion. This specific mechanical system facilitates the application of incremental, tolerable forces to improve both bending and straightening of the joint.[3] Primarily used to resolve joint rigidity and stop the return of deformities after surgery. This orthosis was developed to be an affordable and aesthetically pleasing solution. Furthermore, it offers enhanced medicinal advantages while successfully addressing the technical shortcomings typically found in standard splint designs.

MATERIALS & METHODS

Case Description

The subject was 15 years old who was diagnosed with post traumatic elbow stiffness following a right medial condyle fracture and comminuted capitellum fracture. Despite successful surgical stabilization via open reduction internal fixation, the subject presented with significant arthrofibrosis, restricted passive range of motion limited to 110 degrees at elbow and secondary wrist and finger flexion stiffness.

Aim & Objective of the study

- **Restoration of Functional Range of Motion:** The primary goal is to transition the patient from a "restricted" state to a "functional" range of motion.
- **Addressing Extension Deficit:** The intervention specifically aims to address the patient's lack of elbow extension following surgical fixation.
- **Management of Arthrofibrosis:** The orthosis is designed to treat post-operative elbow stiffness and prevent the recurrence of deformities.

- **Consolidation of Physiotherapy Gains:** The splint acts as a positional "hold" between active therapy sessions to maintain and consolidate the degrees of extension gained during manual mobilization.
- **Remediation of Secondary Complications:** The intervention aims to address secondary finger flexion stiffness by optimizing the length-tension relationship of the extrinsic flexors.
- **Prevention of Deformity:** The design is intended to prevent the development of a "claw-like" resting posture of the hand.
- **Facilitation of Functional Independence:** For adolescent patients, the overarching objective is to support a rapid return to functional independence through a multi-joint approach that ensures distal mobility is not neglected.

Design Concept

The design concept centers on a multi-joint, static progressive approach utilizing the biomechanical principle of stress relaxation to treat severe arthrofibrosis. Unlike dynamic systems that apply constant elastic tension, this design employs a rigid turnbuckle mechanism to maintain periarticular tissues at a constant, preset length (Fig 1). This static displacement allows internal tissue tension to dissipate over time, facilitating permanent elongation and increased range of motion without triggering inflammatory responses. By providing a non-elastic, controllable load, the device allows patients to incrementally adjust tension to their maximum tolerance, significantly enhancing comfort and treatment compliance in adolescent populations.

Furthermore, the orthosis adopts a holistic kinematic chain approach by extending support from the elbow to the wrist and hand. This integration manages the length-tension relationship of the extrinsic flexor muscles, addressing secondary finger stiffness and preventing permanent "claw-like" resting postures. Acting as a rehabilitative bridge, the device serves as a positional hold to consolidate transient range of motion gains achieved during manual physiotherapy sessions. The resulting low-cost, evidence-based design overcomes the limitations of traditional splints to maximize functional outcomes for complex post-traumatic injuries.

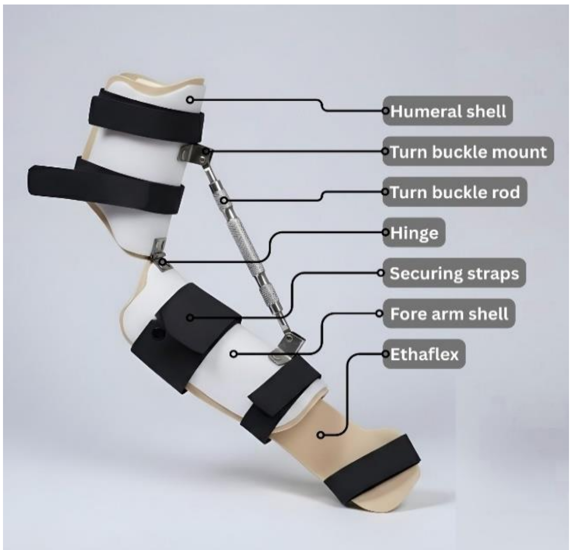

Fig 1: Elbow Wrist Hand Orthosis with turnbuckle mechanism

Fabrication Procedure

After proper assessment and evaluation following measurements were taken for the fabrication of orthosis.

- Medio-lateral measurements of maximum arm
- Medio-lateral measurements of minimum arm

- Elbow joint width
- Medio-lateral measurement of maximum forearm
- Medio-lateral measurement of minimum forearm

The fabrication process commenced with the acquisition of a negative anatomical impression of the patient's right upper extremity with the elbow maintained in the maximum achievable extension and the wrist and hand positioned in neutral alignment. Cling film was applied and necessary markings were done followed by application of plaster of Paris bandages (POP) (Fig 2, 3). After setting, the negative cast was poured by POP powder. After the mould reached sufficient structural integrity, it was removed and utilized to create a positive plaster model. This model was subsequently modified to include relief for bony prominences, specifically the medial and lateral epicondyles and the ulnar styloid, to ensure pressure distribution and patient comfort (Fig 4).

A high-temperature thermoplastic then vacuum-formed over the modified model to create the humeral and forearm shells. These shells were trimmed to allow for adequate joint clearance while ensuring maximum surface area contact for force distribution. A heavy-duty, adjustable stainless steel turnbuckle assembly was then aligned and attached to the humeral and forearm shells. The proximal end of the turnbuckle was secured to the humeral component, while the distal end was integrated into the forearm section, which extended to include a custom-moulded hand platform. This distal extension was specifically designed to maintain the wrist and fingers in an extended position. High-density foam padding and adjustable hook-and-loop fastening straps were applied to the interior and exterior surfaces to facilitate secure donning and doffing while maintaining the structural stability required for static progressive stretching.

Fig 2: Marking of necessary landmarks

Fig 3: Casting for Orthosis

Fig 4: Modification positive cast

RESULT

The clinical application and initial patient trial yielded measurable improvements in joint kinematics. Upon immediate fitment and adjustment of the static progressive orthosis, the patient's passive elbow extension was recorded at 106.16 degrees. This represented a significant acute gain compared to the baseline extension of 98.89 degrees observed without the device. The turnbuckle mechanism successfully facilitated a non-elastic, low load stretch that the patient tolerated without reported discomfort or inflammatory response.

Furthermore, the integrated distal component of the orthosis successfully maintained the wrist and hand in a corrected extended posture, effectively managing the length-tension relationship of the extrinsic flexors. Given these immediate mechanical gains, a favourable prognosis is anticipated with continued use. To monitor long-term tissue remodelling and ensure optimal recovery, the subject has been scheduled for regular clinical follow-up at one- and two-month intervals. These subsequent evaluations will focus on the incremental restoration of the functional arc and the consolidation of range of motion gains achieved through the combined orthotic and physiotherapeutic protocol.

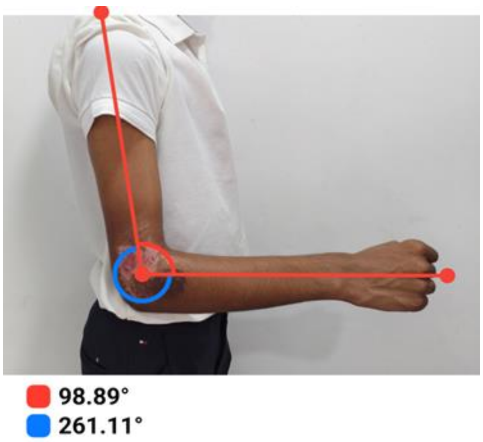

Fig 5: Elbow extension angle without orthosis

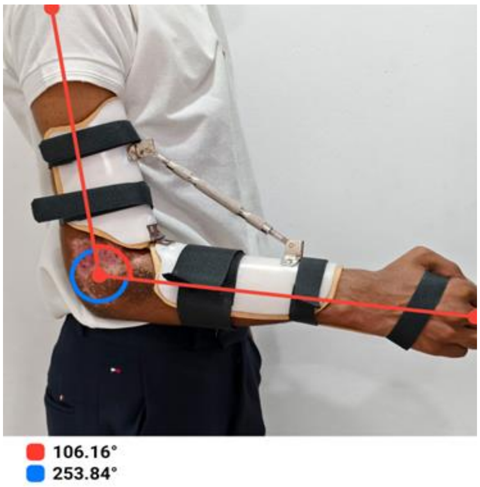

Fig 6: Acute gain of elbow extension angle with orthosis

DISCUSSION

The immediate gain of 7.27 degrees of extension following the initial application suggests that the static progressive mechanism is effective in overcoming the immediate resistance of arthro-fibrotic tissue. This acute change is attributed to the mechanical advantage of the turnbuckle, which allows for precise, incremental loading that facilitates stress relaxation within the joint capsule and surrounding ligaments.

The mechanical principle of stress relaxation involves a decrease in internal tension within a material while it is held at a constant, fixed length. When applied to stiff joint tissues, this constant displacement allows for the biological realignment of fibers and the permanent elongation of the material. In contrast to dynamic splinting—which exerts a continuous force that can exceed the elastic limits of the tissue and cause inflammatory microtrauma—static progressive orthoses provide a controlled load. When the tension of the turnbuckle is set appropriately, the orthosis facilitates tissue expansion without stressing the joint structures beyond their safe physiological threshold. This ensures that the rehabilitative stretch remains therapeutic rather than destructive.[4]

Centering the turnbuckle mechanism along the midline of the limb, rather than positioning it laterally, optimizes biomechanical efficiency. This alignment prevents unwanted rotational forces on the forearm, ensuring that the tension generated by the device is directed purely toward linear joint expansion. By eliminating these torsional compensations, the orthosis achieves a more effective transfer of force to the stiffened periarticular tissues, which can lead to superior gains in the overall range of motion.[4]

A favorable prognosis is anticipated with continued use, as the device serves as a bridge to maintain the range of motion gains achieved during manual physiotherapy sessions. To monitor long-term tissue remodeling and ensure optimal recovery, the subject has been scheduled for regular clinical follow-up at one- and two-month intervals. These subsequent evaluations will focus on the incremental restoration of the functional arc and the consolidation of gains through the combined orthotic and physiotherapeutic protocol.

CONCLUSION

This clinical case demonstrates that a custom static progressive orthosis utilizing a midline-aligned turnbuckle is an effective, evidence-based intervention for managing severe post-traumatic elbow arthrofibrosis. By applying the principle of stress relaxation, the device achieved an immediate extension gain from 98.89° to 106.16°, providing a controllable, non-elastic force that avoids the inflammatory microtrauma often associated with dynamic splinting. The multi-joint design extending to the wrist and hand successfully optimized the length-tension relationship of the extrinsic flexors to remediate secondary wrist and finger stiffness. Ultimately, this orthotic approach, combined with regular follow-up and physiotherapy, facilitates a rapid return to functional independence by consolidating range-of-motion gains in complex adolescent rehabilitative cases.

Declaration by Authors

Acknowledgement: None

Source of Funding: None

Conflict of Interest: The authors declare no conflict of interest.

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How to cite this article: Dibya Ranjan Swain, Priyasmita Naik, Prakash Chandra Prusty, Gayatree Kumari Bhutia, Vidhupriya K K, Abbas Ali T K. Static progressive orthotic intervention for arthrofibrosis following internal fixation of elbow medial condyle and capitellum fractures. *Int. J. Sci. Healthc. Res.* 2026; 11(2): 37-42. DOI: *https://doi.org/10.52403/ijshr.20260205*

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