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Three-Dimensional Surgical Planning and Patient-Specific Osteotomy Guide in the Management of Chronic Monteggia Fracture: A Case Report

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Learning Point of the Article:

Three-dimensional-assisted surgical planning with patient-specific osteotomy guides may improve anatomical correction in chronic Monteggia fracture-dislocation, but careful soft-tissue stabilization and optimization of bone-healing factors remain essential.

Abstract

Introduction: Chronic Monteggia fracture-dislocations, characterized by persistent radial head dislocation and ulnar malunion, pose significant reconstructive challenges. While three-dimensional (3D) printing has shown promise in upper extremity deformity correction, its application in chronic Monteggia lesions remains limited.

Case Report: We report the case of a 24-year-old male presenting with a 1-year history of forearm pain following failed surgical management of a Monteggia fracture. Radiographs revealed a Bado type I chronic Monteggia fracture-dislocation. A personalized 3D-printed osteotomy guide was designed from pre-operative computed tomography data to assist in corrective ulnar osteotomy. The surgical plan included implant removal, corrective osteotomy using a customized surgical guide, bone grafting, and annular ligament reconstruction if unstable radiocapitellar joint after correction. Postoperatively, the patient initially regained functional elbow motion but later developed oligotrophic non-union. Revision surgery with repeat bone grafting resulted in solid union and complete functional recovery.

Conclusion: This case highlights the potential of 3D-assisted pre-operative planning and patient-specific guides in managing chronic Monteggia deformities. It contributes to the growing evidence supporting personalized surgical technologies in complex upper-limb reconstruction.

Keywords: Chronic Monteggia fracture-dislocations, corrective osteotomy, three-dimensional printing, surgical guide, customized plate.

Introduction

Monteggia fracture-dislocations involve a fracture of the proximal ulna with dislocation of the radial head [1] and are commonly seen in pediatric patients but can also occur in adults [2]. While acute cases in adults are typically managed with open reduction and internal fixation, delayed diagnoses or non-anatomical reduction of the proximal ulna fracture may lead to chronic Monteggia lesions characterized by radial head dislocation, ulnar malunion, progressive joint dysfunction, and disabilities [2, 3].

Corrective osteotomy remains the cornerstone of treatment for chronic Monteggia injuries [4, 5]. In recent years, the application of three-dimensional (3D) technology encompassing virtual surgical planning, patient-specific cutting guides, and custom implants has gained popularity in complex deformity correction across various anatomical sites [6, 7].

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Here, we report a case of chronic Monteggia fracture-dislocation in an adult patient successfully managed using 3D-assisted pre-operative planning and a patient-specific osteotomy guide, adding to the emerging evidence on the role of this technology in upper-limb malunions.

Case Report

A 24-year-old male presented with a 1-year history of persistent right forearm pain. He had sustained a Monteggia fracture of the right forearm approximately 1 year prior, initially managed at another institution with open reduction and internal fixation with small dynamic compression plate fixation (Fig. 1a) and subsequently implant removal after fracture union (Fig. 1b). Despite these interventions, he continued to experience pain and dysfunction. Clinical evaluation (Fig. 1c) revealed limited elbow flexion and pronation. The patient, however, experienced pain and discomfort while performing daily activities. The radiographs revealed malunion of the proximal ulna with anterior dislocation of the radial head, consistent with a chronic Monteggia fracture-dislocation (Bado type I) of the right elbow [8].

Surgical technique and 3D workflow

The surgical management was divided into a virtual planning phase and an execution phase using patient-specific instrumentation (Fig. 2). Under general anesthesia and in a supine position, a standard surgical approach was performed along the ulnar crest to expose the deformed bone.

- Virtual Surgical Planning: Pre-operative computed tomography (CT) data of both the affected and contralateral forearms were utilized to create 3D virtual models. The deformity of the right ulna was analyzed by mirroring the healthy contralateral side to serve as an anatomical template, revealing a required correction angle of 25.69°
- Patient-Specific Guide Design: A customized 3D-printed osteotomy guide was engineered based on pre-operative CT imaging to fit the unique cortical topography of the proximal ulnar shaft. This guide incorporated built-in drilling sleeves and a precise cutting slot to dictate the exact location and trajectory of the osteotomy
- Intraoperative Execution: The customized surgical cutting guide was positioned to match the planned anatomical location and secured with 1.6 mm K-wires. Positioning was confirmed with fluoroscopy before pre-drilling the pilot holes for definitive 3.5 mm screws and performing the osteotomy through the guide's designated cutting slot
- Reduction and Internal Fixation: After completing the osteotomy, the separated bone segments were reduced. Precise anatomical alignment was achieved by matching the pre-drilled holes to the corresponding holes in a 3D-printed customized bone plate. Final alignment and implant position were checked to confirm proper correction before proceeding with any necessary radial head stabilization.

Following the ulnar correction, the radial head remained unstable, so an open reduction was performed. The annular ligament was reconstructed using a palmaris longus tendon graft to stabilize the radiocapitellar joint. A temporary transarticular pin was inserted to secure the joint. An autologous iliac crest bone graft was harvested and placed at the osteotomy site. After achieving hemostasis, the subcutaneous tissue and skin were closed. A posterior long arm slab was then applied.

Total operative time was 120 min, with a fluoroscopy exposure time of 49 s. Guide design and manufacturing required 14 days, with an estimated additional cost of 990 USD for the patient-specific guide and implant relative to conventional fixation.

Following the surgical procedure, the patient's elbow was immobilized with a long arm slab for 3 weeks. At that point, the transarticular pin was removed. For the next 3 weeks, the patient was encouraged to perform passive range of motion exercises under supervision. After 6 weeks postoperatively, active range of motion and strengthening exercises were permitted.

Post-operative radiographic measurement demonstrated an achieved correction angle

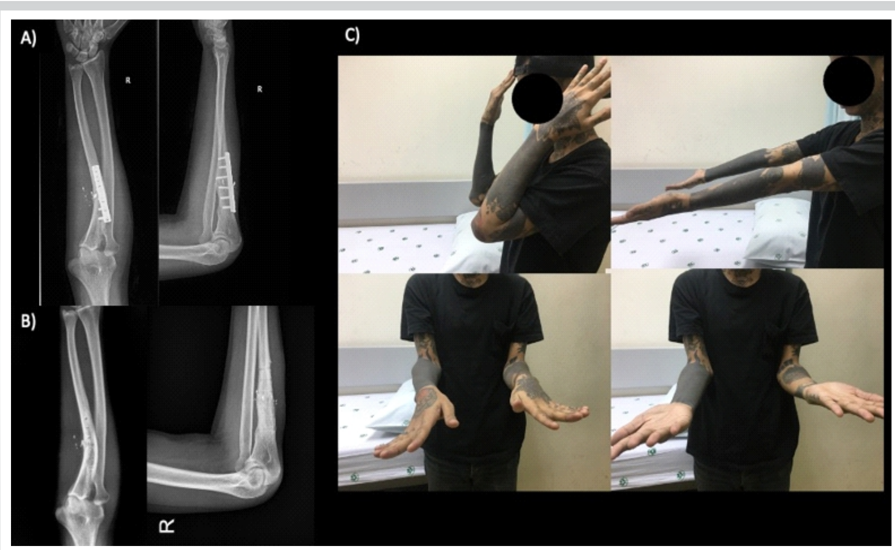

Figure 1: Anteroposterior and lateral radiograph of affected forearm pre- (a) and post-implant removal (b); (c) Clinical pictures of forearm range of motion.

Figure 2: The surgical steps planned for corrective osteotomy using the customized surgical guide and customized bone plate. Pre-operative planning: the deformed right ulna compared with a mirrored image of the contralateral ulna as an anatomical reference, showing the required correction angle of 25.69°. (1) The cutting guide applied on the bone and fixed with 1.6 mm K-wires, followed by drilling of pilot holes for 3.5 mm screws through a 2.5 mm drilling sleeve. (2) A cutting sleeve inserted into the guide and osteotomy performed along the planned cutting plane. (3) The separated bone segments reduced according to the pre-operative plan by aligning the pre-drilled holes. (4) The customized plate fixed to the bone with 3.5 mm screws. (5) Final corrected position of the ulna.

of 22.38°, compared with the planned correction of 25.69°. Post-operative recovery was initially favorable. At early follow-up, the patient achieved an elbow flexion-extension range of motion from 0° to 120°, with 80° of both supination and pronation. However, at 11 months postoperatively, radiographs revealed signs of oligotrophic non-union at the osteotomy site, without bridging callus formation. Notably, the patient had continued smoking throughout the post-operative period.

The patient subsequently underwent revision surgery with repeat bone grafting for the non-union 1 year after the initial osteotomy. Post-operative imaging confirmed progression toward union. At 9 months following the revision procedure, and 1.9 years after the initial corrective osteotomy, the patient had regained functional elbow range of motion, with only mild limitations in forearm rotation. Radiographs demonstrated solid union at the osteotomy site (Fig. 3).

Discussion

Chronic Monteggia fracture-dislocations remain a formidable challenge in orthopedic practice due to delayed diagnosis, malunion of the ulna, and persistent radial head dislocation. These lesions, particularly Bado type I injuries, often present with pain, limited range of motion, and joint instability, significantly impairing function [9]. In such cases, reconstructive strategies must address both osseous deformity and soft tissue imbalance to restore normal biomechanics and prevent long-term complications.

The cornerstone of surgical management in chronic Monteggia lesions is corrective ulnar osteotomy [5]. However, traditional techniques often rely on intraoperative judgment and fluoroscopic guidance, which may lead to suboptimal alignment or increased operative time. Historically, corrective osteotomy for chronic Monteggia lesions was performed freehand, using fluoroscopic landmarks to estimate the osteotomy plane and angulation [2,10]. Techniques such as closing-wedge, dome, or step-cut osteotomies have been described, but their success depends heavily on intraoperative experience and remains susceptible to residual malalignment or recurrent subluxation [2,11]. The overarching goal in managing these injuries is to restore ulnar length and alignment to allow stable

Figure 3: The radiographs demonstrated good alignment of the forearm and radiographic union. (a) The clinical pictures demonstrated range of motion of the affected limb (b).

reduction of the radial head with congruent radiocapitellar articulation [3]. The conventional treatment algorithm begins with ulnar osteotomy and fixation, followed by assessment of radial head stability. If reduction is unstable, adjunctive procedures such as annular ligament reconstruction or temporary transcapitellar pinning are employed [12]. In enduring or irreducible cases, salvage options such as radial head excision or prosthetic replacement may be considered, though they are reserved for refractory cases due to concerns about long-term joint function [3,13].

In this case, we utilized three-dimensional (3D) technology to overcome the limitations of traditional management. In recent years, 3D-assisted techniques have been increasingly applied in upper-limb deformity correction, particularly for distal radius, forearm, and humeral malunions [7]. Pre-operative CT data can be converted into virtual models, enabling accurate assessment of deformity and simulation of corrective osteotomies. Patient-specific guides allow precise transfer of the surgical plan to the operative field, reducing reliance on intraoperative estimation and fluoroscopy. Several series have demonstrated that 3D planning improves accuracy of correction, reduces operative time, and facilitates early functional recovery compared to conventional freehand osteotomies [14,15 16].

Although the application of 3D printing has been increasingly reported in the correction of upper extremity deformities, such as distal radius and forearm malunions, there is a relative paucity of literature focusing specifically on chronic Monteggia fracture-dislocations [11,12]. Only a small number of prior reports, most notably a two-case series describing custom-made surgical guides for malunited forearm fractures with associated radial head dislocation [16], have specifically addressed 3D-assisted correction in this injury pattern. Unlike these prior reports, the present case combines a patient-specific osteotomy guide with a custom-matched bone plate and concurrent annular ligament reconstruction within a single reconstructive strategy for a chronic Monteggia lesion, specifically, a combination not previously described for this injury. Our case supports its potential role in improving anatomical accuracy, joint congruency, and overall functional outcomes in this challenging subset of elbow pathology.

Despite the initial success, our patient developed oligotrophic non-union at the osteotomy site. This was likely multifactorial, with the patient's continued smoking being a significant contributor. Smoking is well-established as a negative modulator of bone healing, and its impact in the context of osteotomy should not be underestimated [17]. Revision surgery with repeat autologous bone grafting ultimately led to union and satisfactory functional recovery. Thus, this case also underscores the importance of addressing modifiable risk factors, such as tobacco use, during pre-operative counseling and post-operative follow-up.

Furthermore, our case incorporated a comprehensive surgical approach combining osteotomy, annular ligament reconstruction, and temporary radiocapitellar pinning. This multimodal strategy likely contributed to early stability and radial head relocation. The use of radiocapitellar pinning, although debated in the literature, provided temporary stabilization, and facilitated ligament healing in our patient [18,19]. An additional aspect highlighted by this case is the importance of interdisciplinary cooperation between surgeons and biomedical engineers in the application of 3D technology. The accurate design of patient-specific guides and implants relies on meticulous communication of clinical requirements to engineers, while surgeons must interpret and validate the virtual plan for feasibility in the operative field. Prior studies in orthopedic oncology and complex limb reconstruction have emphasized that such collaborative workflows improve accuracy, reduce intraoperative uncertainty, and ultimately translate into better functional outcomes for patients [7,14,15].

Conclusion

The successful outcome in this case suggests that 3D-assisted surgical planning may be particularly beneficial in chronic Monteggia injuries where conventional alignment techniques may fall short due to prior surgical alterations or complex deformity, achieving anatomical ulnar alignment and successful radiocapitellar relocation through precise pre-operative simulation and a patient-specific guide. However, the subsequent development of a post-operative non-union in this patient, who continued smoking throughout treatment, underscores that personalized surgical guides must be coupled with strict adherence to biological optimization, particularly tobacco cessation, to achieve reliable union. As 3D printing becomes increasingly accessible and cost-effective, its role in upper-limb reconstruction, particularly in individualized deformity correction, is likely to expand, though larger studies and long-term follow-up are needed to validate its routine use and assess cost-effectiveness compared to standard methods.

Clinical Message

Patient-specific 3D surgical planning and osteotomy guides can improve the precision of corrective ulnar osteotomy and radial head reduction in chronic Monteggia fracture-dislocation. This technical precision must nonetheless be paired with rigorous biological optimization, particularly pre-operative and post-operative tobacco cessation, to achieve reliable bone union.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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