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Original Research

Periprosthetic Ulna Fractures Following Aptis Distal Radioulnar Joint Arthroplasty: A Series of Four Cases

Tan Chern Yang Harmony, MD, [*] Matthew Pina, MD, [*] Tuna Ozyurekoglu, MD, [*] Elkin J. Galvis, MD [*]

[*] Christine M. Kleinert Institute for Hand and Microsurgery, Louisville, KY

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Purpose: This case series presents four cases of periprosthetic ulna fractures following Aptis distal radioulnar joint (DRUJ) arthroplasty to elucidate clinical characteristics, contributing factors, management challenges, and short-term outcomes following this rare complication and to propose prevention and optimal treatment strategies.
Methods: We conducted a retrospective review of 239 Aptis DRUJ prostheses implanted between 2012 and 2022 at a single institution. We identified four cases of periprosthetic ulna fractures and assessed demographics, surgical indications, time to fracture, mechanism of injury, radiographic findings, treatment modalities, associated complications, and outcomes.
Results: The incidence of periprosthetic ulna fractures was 1.7%. All patients had prior surgery on the same extremity. Fractures occurred within 11 months of DRUJ arthroplasty, with varied mechanisms of injury, including one after a fall, another with heavy lifting, and the remaining two unprovoked. Postoperative radiographs revealed eccentric stem position and endosteal impingement in all cases. According to the Unified Classification System for periprosthetic fractures, three were classified as B1 type, and one was B2 type at diagnosis. Open reduction and internal fixation reliably achieved union at an average of 7 months with acceptable function.
Conclusion: Intraoperative technical pitfalls may contribute to periprosthetic ulna fractures during the early postoperative period. Consideration should also be given to anatomical variations and ulna shaft morphometry. Nonsurgical treatment yielded unsatisfactory results, whereas fractures without gross stem loosening treated with open reduction and internal fixation and autologous bone grafting resulted in reliable fracture union, suggesting a limited role for conservative treatment. Based on principles of periprosthetic fracture treatment in other locations, fractures with gross stem loosening may be best managed with implant exchange, with or without supplemental open reduction and internal fixation; however, more evidence is needed to guide the treatment of this rare complication of DRUJ arthroplasty.
Type of study/level of evidence: Therapeutic IV.

The semiconstrained distal radioulnar joint (DRUJ) arthroplasty represents an evolution in the treatment of DRUJ dysfunction. Designed to reestablish the functional anatomy of the DRUJ and forearm, the Aptis DRUJ prosthesis (Aptis Medical) features a grit-blasted intramedullary ulna stem linked to a radius plate via an ultra-high-molecular-weight polyethylene ball.[1–3] Its indications encompass primary and secondary DRUJ osteoarthritis and revision of failed legacy salvage procedures, which include ulna head resection, the Sauvé-Kapandji procedure, or ulna head implant hemiarthroplasty.[1,4–15] It has also been used, albeit less frequently, in cases of distal ulna tumor resection and Madelung deformities.[4,10]

Despite an excellent 5-year implant survival rate of 96% to 100%, the Aptis DRUJ arthroplasty is associated with several complications, among which periprosthetic fractures involving the ulna are rare.[1,4,5,7–10,16] To date and to our best knowledge, there has been only one retrospective review reporting this complication in the literature.[10]

This consecutive case series aims to present four distinct cases of periprosthetic ulna fractures following implantation of the Aptis DRUJ prosthesis observed in a single institution. It sheds light on

Corresponding author: Harmony Tan Chern Yang, MD, Christine M. Kleinert Institute for Hand and Microsurgery, 225 Abraham Flexner Way, Louisville, KY, 40202.

E-mail address: harmony.tan@hotmail.com (T.C.Y. Harmony).

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clinical characteristics, contributing factors, challenges in managing these fractures, and short-term outcomes following treatment. Additionally, we aim to propose strategies for the prevention of this complication and for its optimal management.

Materials and Methods

Institutional review board approval was obtained for this study. We identified all patients who underwent DRUJ arthroplasty using the Aptis prosthesis between 2012 and 2022 at our institution. We used institutional surgical databases and implant logs to identify all patients treated for periprosthetic fractures of the ulna following DRUJ arthroplasty. Demographic information for all patients, including age, hand dominance, occupation, associated medical comorbidities, the indication for DRUJ arthroplasty, the time interval between arthroplasty and fracture, mechanism of trauma, and the presence of prodromal symptoms, were collected.

Radiographs were evaluated for signs of implant loosening (radiolucent zones wider than 2 mm) and fracture pattern.[6] We analyzed the management of each periprosthetic fracture in detail with respect to treatment modalities, complications, and time to union. Lastly, the latest functional and patient-related outcome data, including pain, range of motion, return to preinjury status, and the Disability of the Arm, Shoulder, and Hand (DASH) score were recorded.[17] The DASH score is a 30-item self-reported questionnaire designed to assess the symptoms and physical function of the upper extremity related to daily activities, where a higher score indicates greater disability and severity of symptoms, and a lower score indicates better physical function and fewer symptoms.

Results

Between 2012 and 2022, a total of 239 Aptis DRUJ prostheses were implanted in our institution. The incidence of periprosthetic fracture was 2.5% (6/239). Of these fractures, 2 (33.3%) involved the radius and 4 (66.7%) involved the ulna. The average follow-up duration after the diagnosis of ulna periprosthetic fracture was 31 months (range, 13–60), and for those who underwent surgery, the average follow-up duration beyond their final surgery was 28 months (range, 10–57).

All patients with periprosthetic ulna fractures had undergone at least one previous procedure in the same extremity before DRUJ arthroplasty (mean, 3; range, 1–6). The mean age at which DRUJ arthroplasty was performed was 56 years old (range, 47–66). No patients had notable comorbidities. No intraoperative complications were noted during DRUJ arthroplasty; however, one patient (#4) required deliberate trephination of the ulna cortex to extract retained broken screws.

The average time between arthroplasty and fracture was 7 months (range, 2–11). The mechanism of injury varied across patients, with one fracture occurring secondary to a fall and another because of excessive torque. The remaining two patients had no identifiable trauma. None of the patients experienced prodromal symptoms. Only one out of four patients exhibited features of radiographic implant loosening before sustaining the fracture; however, all patients had radiographic evidence of eccentric reaming with endosteal impingement on initial postoperative radiographs. According to the Unified Classification System (UCS) for periprosthetic fractures, three were classified as type B1 and one as B2.[18] Excluding these patients, evidence of ulna endosteal impingement was also noted on postoperative radiographs in 17 other patients (7.1%) in this cohort. Those patients, however, did not proceed to sustain periprosthetic fractures.

The mean duration of attempted nonsurgical treatment was 4.25 months (range, 2–8). Signs of progressive implant loosening at the stem tip were noted radiographically in all patients during nonsurgical treatment. Surgery was performed to address the fracture in three out of four patients, with one patient (#1) opting against surgery to address a nonunion. The mean time interval between fracture diagnosis and fracture union was 17 months, and the mean time interval between the final surgery and fracture union was 7 months (range, 6–8) (Table S1, available online on the Journal's website at https://www.jhsgo.org).

Case reports

Patient 1

A 65-year-old female underwent extensor tendon reconstruction and left DRUJ arthroplasty for Vaughan-Jackson syndrome secondary to DRUJ osteoarthritis. Her surgical history included a prior ipsilateral distal ulna osteophyte excision and tendon transfer, which did not alleviate her wrist pain and digital extension function.

The DRUJ arthroplasty was performed without complication, and she initially experienced pain relief and improvements in function. However, at 5 months after surgery, she developed a sudden, unprovoked, painful swelling of her left forearm. Clinical evaluation did not reveal gross deformities, but there was focal ulna shaft tenderness accompanied by increased pain during forearm pronosupination. Subsequent clinical radiographs and computed tomography scan revealed a nondisplaced ulna fracture 4 cm distal to the tip of the ulna prosthesis stem (UCS type B1) (Fig. 1B). Retrospective analysis of postoperative radiographs demonstrated eccentric implantation of the ulnar stem, resulting in endosteal impingement (Fig. 1A).

Initial treatment involving immobilization in a long arm cast for 8 weeks, followed by the administration of magnetic bone stimulation (CMF OL1000, Enovis) for a total of 6 months did not result in fracture union. At 1 year post-trauma, she continued to experience mild to moderate pain on forearm rotation and weight bearing. Radiographs at this point revealed the formation of a hypertrophic non-union with progressive volar fracture angulation and ulna stem tip loosening, indicating instability (Fig. 1C). Surgical intervention was recommended. She, however, declined any further treatment. Upon her most recent follow-up, she continued to have pain and was unable to return to her preinjury activities. Her DASH score was 27.5.

Patient 2

A 62-year-old female underwent five previous surgeries at an outside facility to address surgical site infection after open treatment of a distal radius and an ulna styloid fracture. Later, she underwent a radioscapholunate fusion to address post-traumatic radiocarpal arthritis. Following the healing of the fusion, a DRUJ arthroplasty was performed to address symptomatic DRUJ osteoarthritis, and the patient recovered well, being released to full activities.

At 10 months after surgery, she sustained a nondisplaced fracture 4 cm distal to the ulna stem tip (UCS type B1) after falling onto her right forearm (Fig. 2B). Initial treatment involved immobilization in a wrist orthosis for 4 months. Endosteal impingement of the ulnar implant was once again noted on retrospective analysis of her postoperative radiographs (Fig. 2A).

Nonsurgical treatment resulted in progressive fracture displacement and stem loosening (Fig. 2C). Eventually, she underwent nonunion takedown and open reduction and internal fixation (ORIF) using a small locking compression plate (LCP) (Depuy Synthes) supplemented by cerclage wire fixation and autologous

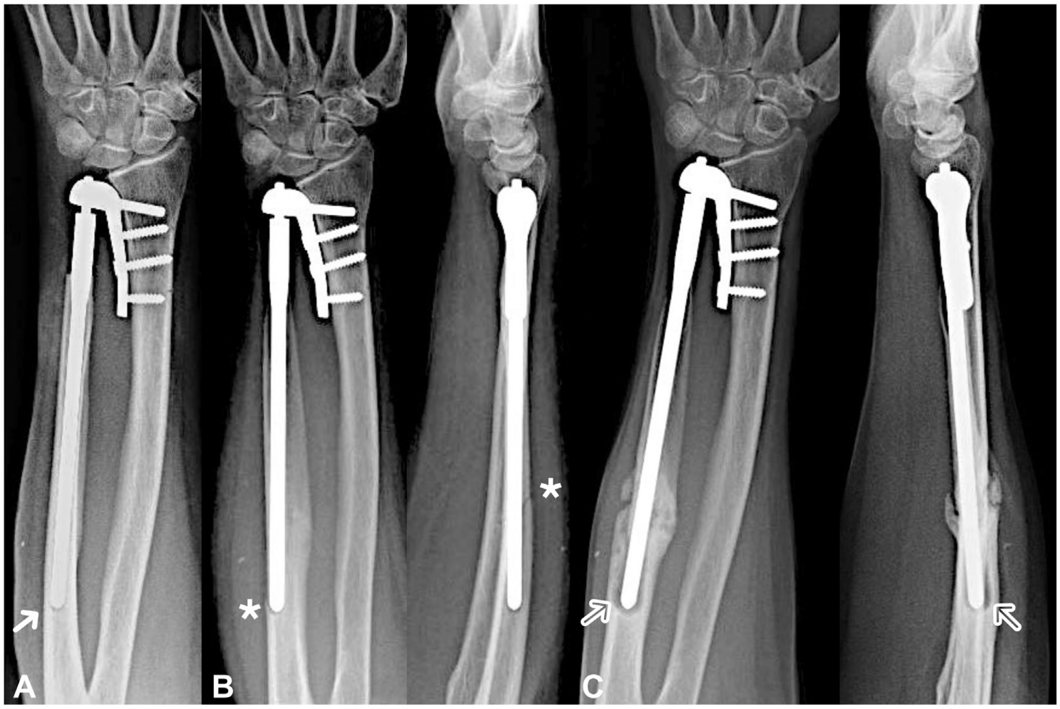

Figure 1. Radiographs of patient 1. **A** Ulna-sided endosteal impingement (solid arrow). **B** Minimally displaced fracture distal to stem tip (asterisks). **C** Progressive loosening around stem tip (hollow arrows) and volar angulation.

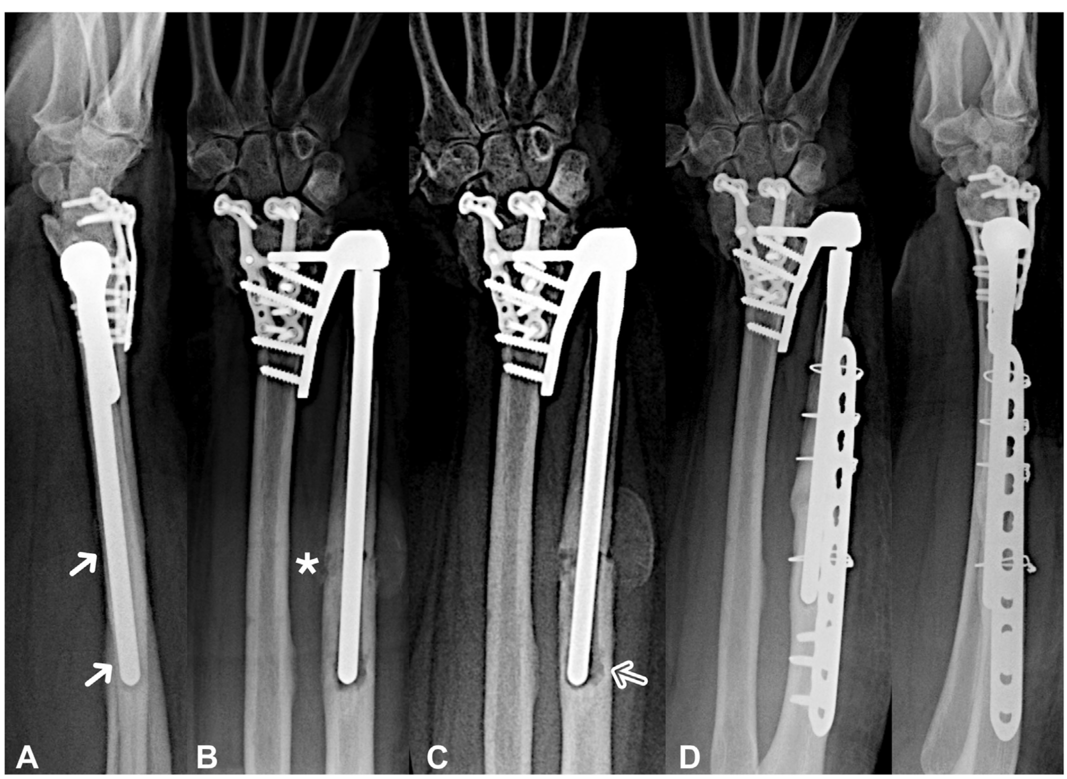

Figure 2. Radiographs of patient 2. **A** Volar-sided endosteal impingement (solid arrows). **B** Minimally displaced fracture distal to stem tip (asterisk). **C** Progressive fracture displacement and stem tip loosening (hollow arrow). **D** Resulting fracture union with ORIF using small LCP and cerclage wire fixation. Also, note the successful radioscapholunate fusion.

cancellous bone grafting. The surgery was complicated by superficial surgical site infection, which resolved with local wound care and oral antibiotics.

Clinical and radiographic fracture union were achieved at 7 months after surgery (Fig. 2D). At her most recent follow-up, the patient demonstrated active wrist flexion and extension range of

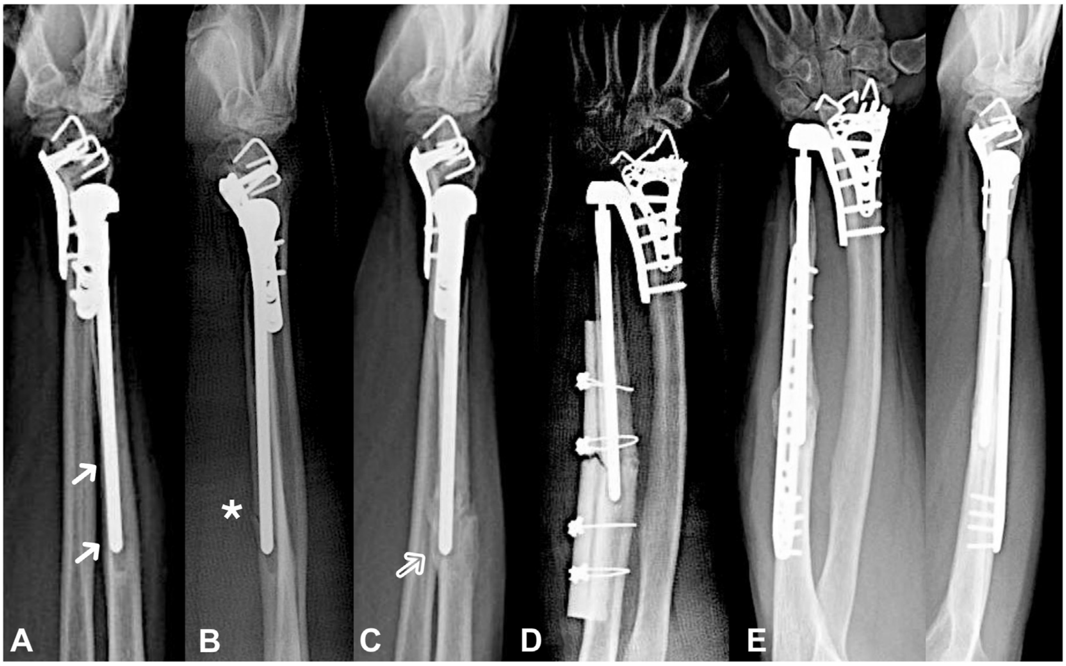

Figure 3. Radiographs of patient 3. **A** Volar-sided endosteal impingement (solid arrows). **B** Minimally displaced fracture distal to stem tip (asterisk). **C** Progressive fracture displacement (hollow arrow). **D** Strut allograft fracture with stem loosening and fracture angulation. **E** Radiographic fracture union with LCP and bicortical screw fixation construct.

15°–15° and active forearm pronosupination of 80°–80° with no reported pain. She was pain free with a DASH score of 28.

Patient 3

A 46-year-old male underwent DRUJ arthroplasty for an ulnocarpal abutment syndrome and DRUJ osteoarthritis, 8 months after sustaining closed intra-articular distal radius and ulna styloid fractures. The initial distal radius ORIF with plate and K-wire was complicated by persistent radiocarpal subluxation, resulting in accelerated radiocarpal osteoarthritis for which a radioscapholunate fusion was performed.

Following DRUJ arthroplasty, the patient had improvements in pain and function. However, he developed a sudden onset of painful ulna shaft swelling while pulling on a heavy object 11 months after surgery. Radiographs confirmed a nondisplaced unicortical fracture 1 cm distal to the ulna stem tip (UCS type B1) (Fig. 3B). Review of postoperative radiographs revealed eccentric implantation of the ulna stem with resultant volar cortical impingement at the fracture site (Fig. 3A).

Initial treatment consisted of immobilization with a long arm cast for 2 months. Interval evaluations showed progressive clinical and radiographic signs of fracture union with resolution of symptoms. However, he developed new-onset pain in the same location 4 months later, and repeated radiographs indicated a refracture at the same site with ulna shaft angulation. The patient underwent another 2 months of immobilization in a long arm cast, followed by a Muenster brace and bone stimulation for an additional 4 months. At this point, progressive implant loosening at the ulna stem tip with the absence of fracture healing was noted (Fig. 3C).

The patient was subjected to a nonunion takedown with cortical strut allografting and cerclage wire fixation. This procedure was complicated by strut allograft fracture 1 month after surgery (Fig. 3D). With no evidence of fracture healing after 6 months, a revision nonunion surgery was performed involving strut allograft removal, autologous corticocancellous bone grafting, and ulna ORIF using a 2.8 mm LCP (APTUS Forearm System, Medartis).

Uneventful clinical and radiographic fracture union occurred 8 months later (Fig. 3E). At the most recent follow-up, the patient did not complain of any pain and had an active wrist flexion and extension range from 45°–45° and active forearm pronosupination from 80°–80°. The DASH score was not available for this patient.

Patient 4

A 47-year-old male underwent three prior surgeries on the same extremity before DRUJ replacement. The initial surgery involved ORIF with a plate and screws for open midshaft fractures of the radius and ulna. Subsequent procedures included an arthroscopic triangular fibrocartilage complex repair for persistent ulna-sided wrist pain and, 1.5 years later, removal of the ulna plate and a Darrach procedure to address undulating symptoms attributed to DRUJ osteoarthritis. The implant removal was complicated by broken and retained proximal screws.

Four months later, the patient underwent DRUJ arthroplasty to address symptomatic radioulnar impingement (Fig. 4). Intraoperatively, trephination of the near ulna cortex was necessary to extract the previously retained broken screws before ulnar component implantation. Postoperative radiographs revealed a sizable ulna-sided cortical defect along with an eccentric stem tip and endosteal impingement (Fig. 5A).

At 2 months after surgery, clinical radiographs indicated a fracture across the cortical defect 5 cm distal to the tip of the ulna prosthesis, with evidence of loosening at the tip of the stem (UCS type B2) (Fig. 5B). The patient denied any history of antecedent trauma or prodromal pain.

A trial of nonsurgical treatment with a Muenster brace for 3 months did not result in fracture healing (Fig. 5C). Five months after the fracture, because of persistent pain, the patient opted to proceed with a nonunion takedown, ulna stem revision, and ulna ORIF (2.8 mm LCP, APTUS Forearm System, Medartis) with autologous corticocancellous bone grafting. A larger diameter and longer ulna stem, which bypassed the defect by 2.5 times the cortical diameter, was used for the component revision.

Figure 4. Weight bearing radiographs of patient 4, showing dynamic radioulnar impingement consequent to a Darrach procedure, which was symptomatic.

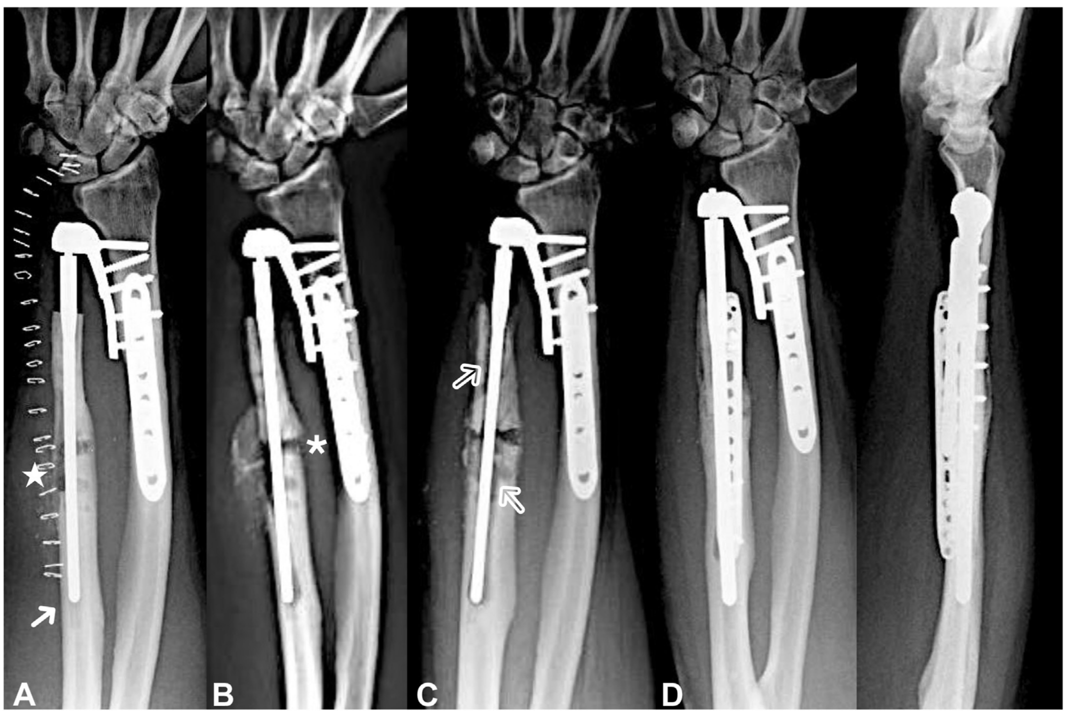

Figure 5. Radiographs of patient 4. **A** Ulnar-sided endosteal impingement (solid arrow) and cortical defect (star). **B** Fracture occurring across the weakened region (asterisk). **C** Progressive, diffuse implant loosening (hollow arrows). **D** Radiographic fracture union with LCP and bicortical screw fixation.

Uneventful fracture union occurred 6 months later (Fig. 5D). On the latest follow-up, the patient reported no pain, and active forearm pronosupination was measured to be 80º–80º. His DASH score was 35.

Discussion

The incidence of periprosthetic fractures related to DRUJ arthroplasty ranges from 0% to 9.5%.[1,2,4,5,7–10,12,14–16,19] The majority of these fractures occurred in the radius, with only one fracture involving the ulna reported in the literature, which was associated with prosthesis explantation because of a concomitant infection.[10] The incidence of ulna periprosthetic fractures in our cohort was 1.7% (4/239). These fractures occurred within 11 months of DRUJ arthroplasty, with the earliest occurring at 2 months after surgery.

Given the rarity of periprosthetic ulnar fractures in the literature, insights can be drawn from principles observed in other implant arthroplasties. A retrospective review of periprosthetic femoral fractures following in-growth femoral prostheses revealed a similar incidence of early fractures within the first year of implantation.[20] The authors hypothesized that medullary canal reaming during the implantation process generated cortical stress risers that contributed to the occurrence of femoral fractures. The fracture risk decreased over time, presumably with osseointegration. Additionally, endosteal impingement in both upper- and lower-extremity arthroplasty has been associated with an increased incidence of fractures around the prosthesis stem tip in uncemented arthroplasty.[21–23] The impingement, acting as a stress riser, amplifies the elastic modulus mismatch between stem material and adjacent unsupported bone.[24–26] Cortical defects, which are frequently encountered in revision surgeries, have also been associated with an increased risk of periprosthetic fractures.[14,20,23,26]

We propose that the early onset fractures seen in our patients, especially considering the radiographic findings and the absence of substantial trauma, likely reflect pitfalls in ulnar medullary canal preparation techniques. To address this, we modified the reaming technique in subsequent cases by keeping the forearm upright during canal preparation, as opposed to lying flat on the operating table as originally described.[1] Reaming in a more vertical direction improved overall access and trajectory for instrumentation of the ulna medullary canal.

Morphometric variations in the ulna shaft should also be considered. A prior cadaveric study by Akpınar et al[27] found an anteromedial and anterolateral bow in the distal one-fifth and proximal one-third of the ulna, respectively. Additionally, the narrowest point of the ulna medullary canal, measuring only 3 mm in diameter, typically occurs in the middle one-third, coinciding with the thickest cortical diameter.[27] The presence of proximal ulna varus angulation should also be contemplated, especially for smaller patients with shorter ulna lengths.[27,28] Should the intramedullary guidewire back out from its final, centralized position, any of these ulna bowing may direct the reamer tip toward the cortex, resulting in eccentric reaming. It is therefore imperative that the position of the guidewire be evaluated repeatedly throughout the reaming process to avoid this. Modifications to the instrumentation, considering these anatomical features, may also facilitate safer stem insertion. For example, the use of a longer intramedullary guidewire of a smaller caliber inserted under strict fluoroscopic guidance may consistently centralize the reamer within the ulna medullary canal. Similarly, the use of a flexible, side-cutting reamer may reduce the risk of cortical disruption.

Given the rarity of ulna periprosthetic fractures, a specific classification is yet to be available. The UCS, which has shown excellent intra- and interobserver reliability, was adopted in this study for its simplicity and plenitude.[18,29−31] Upon diagnosis, three of the four fractures in our series were initially classified as B1 (fracture around the stem with good bone stock and no implant loosening), which is likewise the most common fracture pattern in uncemented humeral and femoral stems.[20,23,32] It is noteworthy that all three of these fractures eventually progressed into type B2 during nonsurgical treatment. The remaining fracture, occurring around a cortical defect, was classified as a B2 type (fracture around the stem with good bone stock and implant loosening).[20,23]

In the absence of implant loosening, ORIF has resulted in the predictable union of periprosthetic humeral and femoral fractures.[20,23,33−35] Biomechanical studies have shown the superiority of constructs involving bicortical screws around a stem compared with alternative fixation constructs.[36−40] However, these findings have not been reflected clinically; a systematic review comparing different surgical fixation methods for type B1 femoral fractures found that LCP fixation was associated with a higher rate of nonunion and hardware failure when compared to cable/cerclage fixation.[34] Nevertheless, variable-angle locking implants with offset screw arrangements (as used in two of our patients) can help facilitate bicortical fixation and provide the surgeon with more fixation options.

Fractures associated with implant loosening are conventionally managed with a prosthetic stem revision to a longer stem bypassing the fracture by two to three cortical diameters.[20,22,33,41,42] However, a recent article by Stoffel et al[43] challenged this dogma and proposed an algorithmic approach to identify stable prostheses, taking into account radiographic features such as minor osteolysis, the absence of stem subsidence, and a fracture location outside the level of stem fixation. This may explain why, although all our patients displayed radiographic signs of loosening around the stem tip at the time of revision surgery, only one patient required implant exchange (with concurrent ORIF) to achieve fracture union. Additionally, the extraction of a well-fixed in-growth distal ulna stem may potentially require a longitudinal osteotomy, which would in turn require supplementary fixation. This is accompanied by risks of catastrophic fracture propagation and subsequent nonunion, making routine implant exchange a less desirable option.[11] Nevertheless, a thorough intraoperative assessment of stem stability must be routinely performed.[43]

Despite contending with nondisplaced fractures at the initial diagnosis, nonsurgical treatment failed to result in fracture union in all patients. Comparatively, nonsurgical treatment of fractures around the tip of humeral implants achieved a union rate of only 14% in uncemented periprosthetic humeral fractures and yielded unsatisfactory results in periprosthetic femoral fractures.[20,23,32] We believe that the presence of the implant likely altered mechanical forces at the fracture site, rendering traditional methods of immobilization inadequate, as evidenced by the progressive implant loosening observed despite nonsurgical treatment.[32] It should also be emphasized that complications following prolonged immobilization and delays in rehabilitation are expected with nonsurgical management, making it less preferable or practical.[22,32]

This study possesses several limitations. Because of the rarity of the condition, our observations and discussions are derived from only a limited number of cases. Consequently, we are unable to formulate clear-cut guidelines or an algorithm for the treatment of ulna periprosthetic fractures in DRUJ arthroplasty. Our proposals stem from both the clinical experience of our senior authors, as well as the relevant literature on fractures involving in-growth prostheses of both the upper and lower extremities. We believe that these observations were highly relevant and applicable, due to the ubiquity and consistency of biomechanical principles as well as fracture healing biology.

Another limitation is the short duration of postoperative follow-up; a longer-term follow-up study will be necessary to evaluate the longitudinal performance of our fixation constructs over time. Additionally, we acknowledge the lack of a comprehensive set of outcome measures in all our patients (eg, lifting capacity, grip, and pinch strength) to better quantify the functional outcomes of our treatment.[1,2,5]

In conclusion, periprosthetic ulna fractures are rare complications following Aptis DRUJ arthroplasty. We speculate that the incidence of early fractures in our series may be linked to eccentric reaming and endosteal impingement. Nonsurgical treatment of these fractures did not result in fracture union but instead led to progressive implant loosening. In the absence of gross implant loosening, reliable fracture healing was achieved with ORIF and autologous bone grafting alone. However, in cases with substantial implant loosening, stem revision in conjunction with ORIF may be necessary. Although the clinical characteristics and outcomes observed here are homogeneous, further evidence is needed to improve our understanding of the behavior of these fractures to help formulate a consistent treatment plan.

Conflicts of Interest

No benefits in any form have been received or will be received related directly to this article.

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