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Review

Management of diaphyseal ulnar nonunion: Current concepts. A literature review

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Abstract. *Background and aim:* Non-union of the ulna presents a significant challenge in orthopedic surgery, often resulting in prolonged pain, dysfunction, and impaired quality of life for patients. The term non-union refers to the failure of bone healing following a fracture, leading to persistent symptoms and functional impairment. Despite advancements in surgical techniques and implant technologies, non-union remains a vexing complication with potential long-term consequences. This review synthesizes, based on the existing literature available, risk factors, type of surgery or second surgery, eventual bone grafts used and management strategies associated with non-union of the ulna. *Methods:*A comprehensive research of the PubMed database was conducted to identify relevant studies on non-union of the ulna. We took into account only full-text articles in indexed journals with available English abstracts, without focusing on clinical studies, case reports, systematic reviews and studies on cadaver or animals. *Results:* In this study 27 articles were included, involving a total of 1.706 patients. The average age of patients were 34,3±18.8 years and the mechanisms of trauma were widely. Studies mainly describe diaphyseal fracture, categorized into 62 atrophic, 51 oligotrofic and 43 hypertrophic nonunion cases. Only 2 cases of septic non-union were described. Different fixation techniques were employed, besides functional outcomes demonstrated significant improvements in the range of motion for both the wrist and elbow. *Conclusions:* In conclusion, this review highlights the complex nature of non-union of the ulna and underscores the importance of further research to better understand its pathogenesis and optimal management strategies. While the literature provides valuable insights into risk factors and treatment outcomes, gaps in knowledge remain, necessitating continued investigation to improve patient outcomes and quality of care. (www.actabiomedica.it)

Key words: ulna, nonunion, diaphyseal ulnar non-union, bone healing

Introduction

Open reduction and internal fixation of the forearm can lead to a variety of complications, including infection, malunion or non-union, nerve injury, compartment syndrome, bleeding, formation of a synostosis and limited function (1). Non-unions are among the most significant complications affecting the complex functional unit of the forearm bones. These bones support and guide the hand movements

through the radio-humeral joint, by the pronation and the supination, and through the proximal and the distal radio-ulnar joints. A non-union of the radius, ulna, or both alters their relationships, causing forearm joint impairment and dysfunction. Furthermore, forearm non-unions may limit the strength of actions such as lifting and gripping (2). A forearm non-union is characterized by the absence of both endosteal and periosteal reaction or no evidence of radiographic progression of healing for six months after the initial treatment (3,4). According to previous studies and research, non-union possibly occur in approximately 2% of all fractures, but the incidence may be higher for diaphyseal fractures (5). Nevertheless, forearm non-unions have a relatively low incidence with typical rates reported in large cohort studies ranging between 2 and 10% (1). Infected non-union of forearm bones are rare, with very few reports in the literature. These cases are especially seen after the treatment of neglected fractures or in patients with a history of smoking, alcoholism, or other comorbidities (6). Factors influencing the development of this condition include the location and complexity of the fracture, which can result from low or high energy impacts, the presence of comminution, soft tissue damage, or whether the wound is open or closed. Additionally, patient characteristics such as age, comorbidities, and surgical techniques play a role in the pathogenesis (1). Non-union can also be associated with inadequate initial reduction of the fracture, unstable fracture fixation, or early limb mobilization (7). In cases of open injuries, significant soft tissue trauma, highly comminuted fractures, inadequate surgical fixation, and patient characteristics that promote infections, septic non-union can develop (2). Fracture non-unions are primarily classified by the biological viability at the fracture ends, assessed by radiographic examination. The main types of non-union are three: hypertrophic, oligotrophic and atrophic. A hypertrophic non-union retains biological potential and callus formation is observable radiographically. It usually fails in the healing process due to mechanical failure from stressors, such as inadequate stability or premature weight-bearing. Oligotrophic non-unions, in contrast, have poor callus formation likely due to biological impairment and excessive motion. An atrophic non-union has such impaired biological potential that callus formation is not visible, and it typically requires a biological stimulus, such as a bone graft, to heal (4,5,8). Most forearm fractures, including septic non-unions, are atrophic and have bony defects (9,2). Surgical technique must provide both mechanical stability and biological stimulation of the bone to restore normal elbow flexion–extension and wrist pronation, supination and grip strength (7). The goal of surgical treatment of aseptic ulnar non-union is to restore the proper anatomical relationship and length between radius and ulna in order to improve function (10).Numerous studies have been published on the treatment of forearm non-union, presenting a wide range of surgical options(7).Surgical management of this condition must consider various factors, such as the patient's age, fracture characteristics, bone and soft tissue quality, and the presence of articular damage.According to Rotini, no surgical treatment is necessary for painless fibrous non-union of the proximal ulna with a range of movement (ROM) greater than 90°. For young patients, the best treatment involves bone fixation using plates and bone grafts. Elbow arthroplasty is a salvage technique used only in elderly patients with severe arthritis and osteoporosis (11). Bone graft and bone substitutes have long been used in post-traumatic non-union in order to promote bone healing and correct bone defects. There are different options including cancellous or cortical bone, both autologous and homologous, autologous bone marrow and calcium phosphate-based bone graft substitutes. Each of those with its own pros and cons (4). For treating ulnar shaft non-unions, techniques included distraction-compression osteogenesis, locked plating and locked intramedullary nailing. Additionally, free fibula transfer flaps have been advocated to restore anatomic length and ensure bony union (10). Regarding septic forearm non-union, their treatment may have some difficulties represented by bone infection, poor bone quality resulting from the septic process, bone necrosis, and scar adhesion of the soft tissue due to multiple previous surgeries.Proper treatment of this type of non-unions should first aim to eradicate the infection and then promote bone healing (2). Management options include staged debridements followed by internal fixation after infection control or single-staged debridement with the

application of an external fixator (6). We aim to summarize the available evidence in the literature on ulnar non-union management to give a systematic overview of this rare although complex pathology, which is still difficult to approach and treat.

Materials and Methods

Study setting and design

The present investigation represents a systematic literature review reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines via PubMed, Medline and the Cochrane Library database. The bibliography of the selected studies was accurately searched by hand, to identify further studies not found during the electronic search. No restrictions were applied concerning the date of publication. The title of the journal, name of authors, or supporting institutions were not masked at any stage.

Inclusion and exclusion criteria

In this review we considered the studies published as full-text articles in indexed journals, which investigated the risk factors, type of surgery or second surgery, eventual bone grafts used and management strategies associated with non-union of the ulna. Only articles written in English with available abstracts were included. No publication date limits were set. Surgical technique reports, expert opinions, letters to the editor, studies on animals, unpublished reports, cadaver or in vitro investigations, review of the literature, abstracts from scientific meetings, book chapter were excluded from the present review. Two independent reviewers (G.M.S and A.S.) collected the data from the included studies. Any discordances were solved by consensus with a third author (F.L.). All abstracts were reviewed to determine adherence to inclusion and exclusion criteria of our study. If no abstract was published or if the abstract did not have sufficient information to determine eligibility, the full-length manuscript was reviewed. Articles with questionable data were discussed with the senior author. For each study included in the present analysis, the following data were extracted: main author, year of publication, article type, number of patients included, the sex of the enrolled patients,age,type of fracture, comorbidities, traumatic mechanism, type of surgery, time to first surgery, type of surgical fixation, complications, type of nonunion,pre operative ROM post-operative outcomes, time from surgery to the diagnosis of non-union, time to second surgery, use or nor of bone graft, type of bone graft, time of follow up.

Data availability

The data associated with the paper are not publicly available but are available from the corresponding author on reasonable request.

Results

The study flow chart is shown in Figure 1. An initial literature search resulted in 372 articles, from which duplicates were removed. The remaining papers were screened based on their titles and abstracts. After excluding non-English papers, the articles underwent full-text assessment for eligibility. From this analysis, no additional articles were included through references found in the assessed full-text papers. Papers that did not meet the inclusion criteria, and those for which additional data was not provided by corresponding authors after an official request, were excluded. Ultimately, 27 papers were included in this systematic review. They were published between 1988 and 2023, involving a total of 1.706 patients. The reported gender distribution includes 761 males and 361 females, with ages ranging from 11.2 to 78 years and an average age of 34,3±18.8 years. Mean follow-up in the included studies were 25,5± 23,3 months. The mechanisms of trauma varied widely, including falls, motor vehicle accidents, industrial accidents, and sports-related injuries, including some cases of low-energy trauma (12,13). Treatment methods were diverse, ranging from various forms of internal fixation, such as plating, intramedullary pinning, Kirschner wires, tension bands, and external fixation. Only a few studies opted out for closed reduction and casting (12,14,15). Fracture localization showed a large predominance of

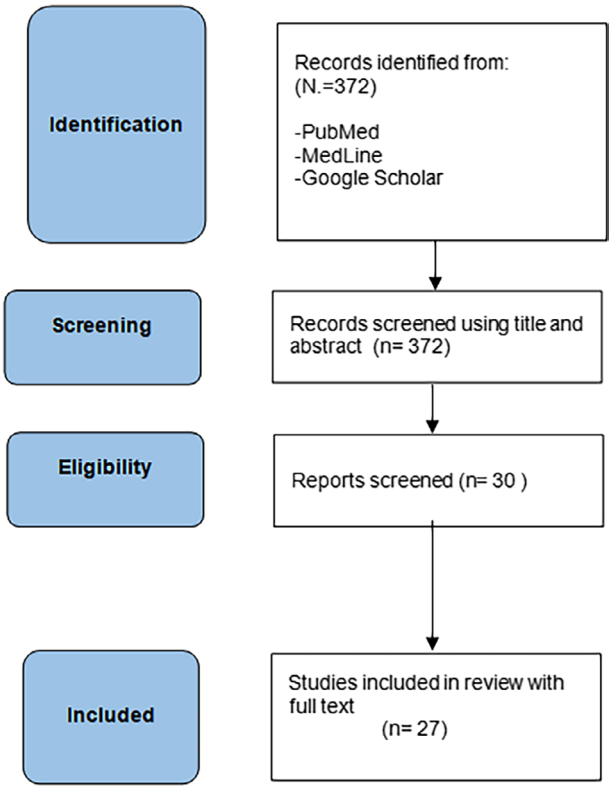

Figure 1. PRISMA Flowchart.

diaphysealfracturesoftheulna,withasmallrepresentationof Monteggia-like fractures (16,17). Nonunion cases were categorized as atrophic, oligotrophic, or hypertrophic, 62, 51 and 43 patients, respectively. Mean time from surgery to the diagnosis were 6,9±2,7 months. Aseptic non-union were the large majority of the cases, meanwhile, septic non-union were mentioned only in two studies (18,19). They were managed through repeat surgeries, and fixation. Different fixation techniques were employed, and some studies reported the use of casts post-operatively, re-fixation andextensive use of bone graft, with only one study referring to not use any graft (17).Post-operative outcomes indicated improvements, with DASH scores showing enhancements where reported (3,20-22) and Grace and Eversmann scores ranging from excellent to average results, however it was reported only in two studies (3,23).Functional outcomes demonstrated significant post-operative recovery in the range of motion for both the wrist and elbow, with notable improvements in flexion and extension (1,3,10,18,21-27).

Discussion

This study provides a comprehensive analysis of the current literature on ulnar non-union management (Table 1). Forearm non-unions, although a relatively uncommon complication (2-10% of fractures) (1), can significantly impact a patient's hand function and overall quality of life (28). The study effectively summarizes the various factors contributing to non-union development, including fracture location, severity, and patient characteristics (1). The classification system based on biological activity at the fracture site (atrophic, oligotrophic, and hypertrophic) offers a valuable framework for guiding treatment decisions (5). Notably, the study highlights that most forearm non-unions, including septic cases, are atrophic and often present with bony defects (29). The importance of achieving both mechanical stability and biological stimulation for successful bone healing is emphasized (30). The discussion can be further strengthened by elaborating on specific surgical techniques employed for different non-union types. For instance, mentioning the advantages and disadvantages of plates, intramedullary nails (31), and bone grafting procedures in various clinical scenarios would provide surgeons with more practical insights.The study acknowledges the challenges associated with treating septic non-unions, including infection eradication, bone quality deficiencies, and soft tissue scarring. It would be beneficial to delve deeper into the management strategies for septic non-unions, potentially outlining the role of staged debridement, antibiotic therapy, and specific fixation techniques.In conclusion, this study offers a valuable contribution to the understanding of ulnar non-union management. By incorporating the suggested enhancements regarding surgical techniques and in-depth discussion of septic non-union treatment, the discussion section can be further enriched to provide an even more comprehensive and informative resource for orthopedic surgeons.

Conclusion

Forearm non-unions are uncommon but extremely challenging. Operative treatment with internal fixation, such as plating, intramedullary pinning,

Table 1. Main demographical and clinical data from the included studies

Article	Year	Num of patients	M/F	Age	Comorbidity	Mechanism of trauma
Adamczyk et al	2005	6	-	15.3	no	low energy /1 high
Boussakri et al	2016	21	16/5	34.5	1 addicted to smoking and reflex sympathetic dystrophy syndrome.	-
Dos Reis et al	2009	19	-	30	1 cardiovascular	-
Mehdi Nasab et al	2012	28	-	34.9 ± 12.5	-	-
Pagnotta et al	2012	2	1/1	40-32	-	-
Ring et al	2001	10	6/4	47	-	-
Flynn et al	2010	149	112/37	11.2	no	-
Abalo et al	2007	173	-	36	no	motor vehicle accident (n=98), industrial accident (n=20), and fall (n=66).
Sinikumpu et al	2012	168	117/51	<16	neurofibromatosis in one	trafficaccident
Lee et al	2008	20	-	41	-	-
Schuind et al	1988	93	-	11.22	-	trafficaccident, fall
Henle et al	2010	45	-	18-72	-	motorcycle, sport, bycicle, leisure activity, work
Prasarn et al	2009	14	8/6	19-79	-	fall, car accident
Babhulkar et al	2005	18	-	-	-	-
Mikek et al	2004	157	-	-	-	-
von Rüden et al	2015	49	-	mean 43-45	-	-
Gupta et al	2010	20	13/7	25-68	-	-
Lee et al	2013	67	-	-	-	-
Garg et al	2006	21	14/7	11.8	-	simple falls and falls from height, sports related injuries
Ross et al	1989	94	72/22	15-70+	-	-
Puvanesarajah et al	2015	12	4/8	39.0	Osteogenesisimperfecta	-
Vasara et al	2023	470	302/168	38 (27-54)	(68 smoking 39 alcohol abuse 20 intravenous drug abuse 24 diabetes 4 previous neuropathy 5 atherosclerosis 121 other considerable injuries 36 ipsilateral extremity injuriy)	156 falling <1 m 35 falling 1-3 m 12 falling >3 m 36 car accident 43 car accident 43 motorbike accident 8 car hitting pedestrian or cyclist 40 bicycle injury 12 skate injury 20 crush injury 11 torsion injury 54 direct impact or assault 20 contact sport injury 23 other or unspecified injury

Table 2 (*Continued*)

Article	Year	Num of patients	M/F	Age	Comorbidity	Mechanism of trauma
Choi et al	2021	8 (5R, 3U)	4 (3R, 1U)/4 (2R, 2 U)	38(18-52)	-	5 fall 1 car accident 1 motorcycle accident 1 arm rolled into machine
Heo et al	2022	10	0/10	78 (71-83)	All osteoporotic patients in therapy with bisphosphonates. In addition, 6 patients had:hypertensionDiabete, stroke, rheumatoid, arthritis, dementia	10 accidentalfall 2 atraumatic
Kloen et al	2010	47	35/12	37 (16-76)	-	26 motor-vehicle accident 12 fall 9 crush injury
Tall et al	2014	50	38/12	40,9 (17-60)	-	47 traffic accident 3 fall from an elevated height
Saka et al	2014	8	5/3	39 (19-55)	-	5 motor-vehicle accident 2 fall 1 industrial accident

Kirschner wires, tension bands and external fixation was applied with positive impact in patient's dailylife. Bone graft must be performed to accelerate healing (specifically in case of osseous defects up to 6 cm) as well as to prevent non-unions. Furthermore, free tissue transfer must be taken into account for even larger defects.In summary, our study suggests that when adequate treatment techniques are applied, the vast majority of patients with forearm nonunions can be brought to union both clinically and radiologically and obtain a satisfactory long-term functional outcome. However, further studies and investigations are required to provide a wider range of procedures in order to prevent and to heal forearm non-unions.

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

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