Advancements in the Management and Treatment of Distal Radioulnar Joint Dislocation

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Abstract: Distal radioulnar joint dislocation (DRUJ) is a prevalent clinical condition often resulting from wrist trauma or forearm fractures. A variety of treatment modalities are available, each with distinct advantages and limitations. Selecting an appropriate treatment strategy based on the patient's specific condition and functional requirements is crucial. Appropriate management significantly influences prognosis and can effectively mitigate complications such as local pain and joint instability. This review synthesizes extensive literature to provide an overview of DRUJ treatment approaches.

Keywords**:** Distal radioulnar joint; Dislocation of joints; Conservative treatment; Surgical treatment

1. Introduction

The distal radioulnar joint (DRUJ) plays a critical role in the pronation and supination of the human forearm and may become dislocated as a result of wrist injuries or forearm fractures [1]. Simple DRUJ dislocations are relatively uncommon in clinical practice, typically occurring in conjunction with distal radius fractures, with an incidence rate ranging from 10% to 19% [2]. Although DRUJ dislocations are not rare, their management remains a subject of debate within the academic community, particularly concerning the selection of appropriate treatment protocols. Common therapeutic approaches include manual reduction and fixation, the Darrach procedure, the Sauve-Kapandji procedure, and DRUJ reconstruction [3], each presenting distinct advantages and limitations. Selecting the most suitable treatment is essential for optimizing patient outcomes and minimizing complications such as local pain and joint instability. Despite the limited body of research on DRUJ dislocation, growing societal progress, advancements in science and technology, and improvements in medical standards have heightened patients' expectations for quality of life, thereby increasing attention to DRUJ dislocation. This article aims to provide a comprehensive review of the latest advancements in DRUJ dislocation treatment by systematically analyzing relevant literature.

2. Anatomical Characteristics of the Distal Radioulnar Joint and Their Biomechanical Implications

The distal radioulnar joint (DRUJ) comprises the distal radius, ulnar head, and triangular fibrocartilage complex (TFCC). The stability of this joint primarily relies on the intrinsic stabilizing function of the TFCC. The TFCC is composed of the central disc, dorsal radioulnar ligament, and palmar radioulnar ligament. The central disc prevents compression within the complex and provides tension during joint movement. The dorsal radioulnar ligament becomes taut during pronation and relaxes during supination, while the palmar radioulnar ligament exhibits the opposite behavior. Additionally, the ulnocarpal ligament, ulnar collateral ligament, and the depression around the ulnar styloid process form a complex structure that intertwines with the ulnar head ligaments, enhancing overall stability. The structural characteristics of the TFCC play a crucial role in the pronation and supination of the DRUJ by controlling the rotation and translation of the ulnar head relative to the sigmoid notch of the distal radius. It serves as the primary intrinsic stabilizer of the DRUJ. According to Jawed et al. [5], the TFCC acts as an internal stabilizer for the DRUJ, and its tear can lead to varying degrees of DRUJ instability and ulnar wrist pain [6]. In daily activities, when the forearm initiates pronation or supination, the angle of the axle joint formed by the sigmoid notch of the distal radius and the ulnar head changes significantly. The difference in the radii of curvature between these two surfaces makes the joint susceptible to dislocation towards the volar or dorsal side during violent movements [7]. The sigmoid notch and ulnar bone at the distal radius constitute the skeletal framework of the DRUJ. However, due to the shallow nature of the sigmoid notch, its radius of curvature is only 50%-60% larger than that of the ulnar bone, contributing to the inherent laxity of the DRUJ.

3. Nonsurgical Management

The non-surgical management of DRUJ dislocation typically involves a series of interventions including closed reduction, immobilization with small splints or casts, brace application, oral administration of non-steroidal anti-inflammatory drugs (NSAIDs), topical traditional Chinese medicine, dietary adjustments, and psychological support. Dai Jianhua et al. [8] conducted a retrospective analysis of 20 patients with acute DRUJ dislocation treated using manual reduction techniques developed by Dai and "sandwich" fixation with crescent-shaped small splints and paper pressure pads. The study reported an 85% excellent to good rate in the Krimmer wrist score at final follow-up, indicating that this approach effectively enhances wrist function in patients with acute DRUJ dislocation. Dai Gorong et al. [9] managed 56 cases of DRUJ dislocation (44 of which were acute injuries) through manual reduction and small plate fixation. Long-term follow-up revealed an overall excellent to good rate of 82.15%, with all six poor outcomes occurring in chronic cases. These findings suggest that conservative treatment is more effective for acute dislocations, while chronic dislocations tend to have less favorable outcomes. For patients experiencing severe instability post-injury or persistent instability following several weeks of conservative management, surgical intervention is currently preferred in clinical practice [10].

4. Surgical intervention

4.1 The Darrach procedure

Darrach surgery, or ulnar head resection, has been recommended for the treatment of traumatic distal radioulnar joint (DRUJ) dysfunction since it was popularized by Moore in 1880 and Darrach in 1913 [11]. Studies have demonstrated that this procedure can significantly alleviate pain; however, it may also result in distal ulnar instability, which can subsequently impact the radius, potentially leading to forearm rotation, diminished grip strength, and clicking at the ulnar stump. Consequently, the Darrach procedure is generally more suitable for elderly patients or those with lower functional demands on their wrists [12]. Bell et al. [13] first described the ulnar and radial impingement syndrome as a complication of the Darrach operation, characterized by pain at the ulnar stump, reduced function during pronation or supination, and loss of wrist joint strength. Regarding remedial measures following Darrach surgery failure, some studies [14] have found that ulnar head replacement can effectively address ulnar stump instability, with all patients experiencing significant improvements in pain relief, range of motion, and stability.

4.2 Sauve-Kapandji procedure

The Sauve-Kapandji procedure is a well-established surgical technique extensively utilized in the management of distal radioulnar joint (DRUJ) disorders. This procedure is particularly indicated for conditions such as rheumatoid arthritis, osteoarthritis, post-traumatic arthritis, and congenital malformations associated with DRUJ dislocation, and has demonstrated significant clinical success [15]. The key components of the surgery involve DRUJ arthrodesis and resection of the distal ulnar lesion while preserving the ulnar support structures of the carpal bones, including the distal radioulnar ligament and the ulnocarpal ligament. By maintaining the integrity of the triangular fibrocartilage complex (TFCC) and its associated ligaments, along with the ulnar head, normal force transmission of the wrist joint is ensured, thereby effectively restoring joint function. This approach is especially beneficial for younger patients with high demands on wrist functionality, particularly in cases of post-traumatic DRUJ dislocation [16]. However, the Sauve-Kapandji procedure is not without potential complications, which may include painful instability of the proximal ulnar stump, heterotopic ossification near the ulnar resection site limiting wrist pronation-supination, and discomfort from internal fixation devices [17]. Notably, painful instability of the proximal ulnar stump is the most prevalent complication. According to Brunet et al. [18], all patients who underwent the Sauve-Kapandji procedure exhibited instability of the proximal ulnar stump, with more than half experiencing pain during pronation.Kazuaki et al. [19] proposed that the observed instability might result from the fusion of the ulna and radius, mutual irritation between the damaged distal ulna and adjacent tissues. To address this issue, they introduced an innovative technique involving the complete release of the pronator quadratus (PQ) muscle from its volar and ulnar insertions on the radius, followed by its transfer dorsolaterally through the interosseous space to cover and stabilize the proximal ulna stump. Given that the PQ is one of the primary muscles connecting the two forearm bones, this method prevents radioulnar convergence and minimizes stimulation of the proximal ulna stump, thereby reducing pain. In recent years, orthopedic surgeons have been investigating methods to mitigate complications associated with the Sauve-Kapandji procedure. For instance, Li Jianqiang et al. [20] combined flexor carpi ulnaris fixation with a modified Sauve-Kapandji surgery in 24 cases. Postoperative follow-up revealed no ulnar stump instability or pain, and X-ray examinations confirmed successful distal radioulnar joint fusion with satisfactory outcomes. Additionally, Fangyi et al. [21] utilized iliac bone grafting instead of traditional ulnar bone grafting to enhance fusion stability while preserving approximately 1.0 cm of the ulna segment, achieving favorable clinical results.

4.3 Arthroscopic surgery

In the past three decades, arthroscopic technology has experienced rapid development and made significant progress in the field of orthopedic treatment. Compared with traditional open joint surgery, arthroscopic surgery has the advantages of rapid recovery, less trauma, lower cost, more complete treatment effect and higher safety, so it has become the preferred method for many orthopedic surgeons to deal with knee and wrist joint injuries [22]. As the most important stable structure of the distal radioulnar joint (DRUJ), the triangular fibrocartilage complex (TFCC) not only plays a role in shock absorption, but also plays an important role in maintaining the stability of DRUJ. Its damage can easily lead to DRUJ instability. At present, arthroscopy is considered to be the most accurate method for the diagnosis of TFCC injury [23], and the repair of TFCC assisted by arthroscopy has become one of the important means for the treatment of TFCC tears. Palmer classification is widely used to describe TFCC injury in clinical practice, which is divided into type I (traumatic tear) and type II (degenerative tear) according to the location and chronic degree of the tear. Palmer type I is further subdivided into five subtypes [24]. Studies have shown that when Palmer Ib, IC and ID TFCC lesions affect the attachment point of the distal radioulnar ligament, whether accompanied by fracture or not, they will cause DRUJ instability to varying degrees. Atzei et al. further subdivide Palmer type IB lesions into five subtypes, among which Atzei type 2, 3, and 5 TFCC lesions similarly lead to DRUJ instability [25]. For Atzei type 2 TFCC injury, transosseous tunnel or suture anchor is usually used in clinical practice to repair the ulnar end tear [26].High-energy injuries often lead to Palmer IC TFCC lesions, involving the volar external ulnar ligament complex (including tears or avulsions of the ulnarunate ligament and the ulnar deltoid ligament), and then causing instability of the distal radioulnar joint (DRUJ). TFCC lesions of Palmer ID type involve avulsion of bony structure or soft tissue from the sigmoid notch of the radius, often accompanied by fracture, so the incidence of DRUJ instability is high. Nevertheless, studies have shown that these two subcategories can also be treated by all-arthroscopic repair, which has been proved to be effective, reliable and safe, but more clinical data are still needed [7]. Abe et al. [30] tried the arthroscopic Sauve-Kapandji procedure, and the results showed that this procedure could successfully reduce the ulnar head into the sigmoid incision while maintaining the anatomical position, and retain the vascular supply of the DRUJ without interference with the extensor mechanism, thus allowing the patients to recover early. However, this procedure requires high arthroscopic techniques and skills, especially when dealing with extensor tendon rupture, which may weaken the advantages of arthroscopy. There is also a risk of instability of the proximal ulna stump and radioulnar joint fusion. Therefore, ensuring the stability and safety of the arthroscopy-assisted Sauve-Kapandji procedure is the focus of future research.

4.4 DRUJ reconstruction

In recent years, DRUJ (distal radioulnar joint) reconstruction including extra-articular reconstruction and intra-articular reconstruction has been widely used in clinical practice. The common extra-articular reconstruction methods mainly include closed reduction and Kirschner wire fixation and titanium plate fixation. Closed reduction and percutaneous Kirschner wire fixation is the most commonly used internal fixation method in clinical practice. The fixation of the dislocated ulna and radius through Kirschner wire has the advantages of simple operation, low cost and low technical requirements for the operator. However, this method has potential complications, such as secondary fracture, Kirschner wire fracture and joint stiffness [31]. In order to reduce these complications, Bai Weifei et al. [32] proposed the combination of partial transposition of pronator quadratus muscle and Kirschner wire internal fixation. In the 48-week follow-up of 13 patients, the recovery of wrist joint function was better than that of simple Kirschner wire internal fixation, and the incidence of complications was lower. The principle of titanium plate fixation is similar to that of Kirschner wire internal fixation. Both of them restore joint stability by fixing the DRUJ. Tang Zhao et al. [33] used titanium plate fixation to treat DRUJ dislocation in 25 patients. According to Gartland-Werley wrist score at the last follow-up, 23 cases were excellent and 2 cases were good, with significant curative effect. Intra-articular reconstruction such as anatomical reconstruction of the distal radioulnar ligament (DRUJ) is a complex technique. Although effective in treating DRUJ dislocation, it requires cutting the joint capsule and drilling a circular tunnel into the ulnar head to allow the palmaris longus tendon to cross. This may affect the blood supply of the TFCC (triangular fibrocartilage complex), thereby compromising this important intrinsic stable structure. It affects postoperative recovery [34]. Although the above reconstruction methods have their own advantages and disadvantages, they all have certain limitations. Recently, Liu et al. [1] proposed a button plate suspension fixation method to reconstruct DRUJ dislocation, which is easy to operate, minimally invasive, and highly reproducible, and is conducive to early postoperative rehabilitation. It does not require intra-articular or extra-articular ligament reconstruction, does not damage adjacent joint structures, supports early functional exercise, and achieves satisfactory postoperative functional recovery. This provides a new option for future reconstruction of DRUJ stability.

4.5 Artificial joint replacement

In recent years, DRUJ prosthesis technology has made significant progress and is widely used to treat complications after Sauve-Kapandji and Darrach procedures, such as DRUJ instability and pain, as well as DRUJ damage caused by rheumatoid arthritis, degenerative arthropathy, and post-traumatic arthritis. These conditions cannot be effectively treated by other means [35]. Scheker prosthesis is one of the most widely used DRUJ prosthesis in clinical practice. It consists of an ulna stem in medullary cavity and an ultra-high molecular weight polyethylene (UHMW) ball, and is stabilized by a plate fixed to the radius, which can functionally replace the ulna head, sigmoid tubercle notch and DRUJ ligament [36]. Brannan et al. [37] performed DRUJ joint replacement with Scheker prosthesis in 21 patients, and the results showed that the patients had good clinical results after surgery, with a median postoperative DASH score of 26.7, a median VAS pain score of 0.6 at rest, and a median VAS pain score of 2.1 during activity. Supinator strength was recovered with only mild pain and a moderate complication rate of 29%. The study by Levina et al. [38] also showed that, despite a small sample size, Scheker prosthesis showed positive effects in reducing pain, improving DASH functional assessment, increasing pronation and supination range of motion, and patient subjective satisfaction, and prosthesis survival rate reached 100%. In summary, Scheker prosthesis has shown satisfactory results in almost all reports for effective restoration of wrist function, good long-term efficacy and wrist stability with few complications, and can be considered as the first-line treatment for reconstruction of this joint. However, longer follow-up is needed to further verify its reliability.

5. Discussion

DRUJ dysfunction seriously affects the quality of daily life of patients, and its recovery is still an urgent problem to be solved. In clinical practice, attention should be paid to the collection of patient's medical history, especially the history of wrist trauma, in order to suspect the existence of DRUJ dislocation, and early diagnosis and intervention through X-ray, CT, MRI and other imaging examinations, so as to avoid the development of obsolete dislocation. Conservative treatment has the advantages of non-invasive, low cost and simple operation, but its effect in joint fixation and reduction is not as good as surgical treatment. Surgical treatment can better repair the damaged muscles, ligaments and joints, but there are more complications. Regardless of conservative treatment or surgical treatment, the ultimate goal is to restore joint and muscle function. The choice of treatment should be based on the individual condition of the patient and the specific condition of DRUJ injury. For patients with fresh and stable dislocations and patients with low functional requirements, non-surgical treatment can be used as the first choice, while for patients with high functional requirements and non-surgical treatment cannot restore forearm stability and function, surgical treatment should be considered to repair bone and ligament injuries. Darrach surgery and Sauve-Kapandji surgery have a history of more than 100 years. Both of them can effectively relieve pain, but Sauve-Kapandji surgery is better than Darrach surgery in the recovery of wrist joint function, so the application range is wider [39]. With the emergence of new and improved surgical procedures, the complications of the two procedures are expected to be improved. Although DRUJ reconstruction can effectively fix the injured joint, and the operation is simple and the cost is low, there is a risk of secondary injury in the joint, which should be carefully selected in clinical application. Arthroscopic surgery is favored for its advantages of minimal invasion and rapid recovery, but it requires high operating skills of the surgeon, and skilled operation skills directly affect the prognosis of patients [40]. Artificial joint replacement can significantly improve the function of the wrist joint, with good long-term efficacy and stability, and few complications. It can be regarded as the first-line treatment for the reconstruction of the wrist joint, but its long-term efficacy still needs to be further verified.

In summary, with the in-depth study of the functional anatomy and biomechanics of DRUJ, the treatment of DRUJ dysfunction has made significant progress. Orthopedic surgeons should explore the repair or reconstruction methods in accordance with its anatomical structure and biomechanical characteristics to reduce the occurrence of complications. In the future, conservative treatment will pay more attention to the improvement of fixation materials, and surgical treatment will tend to be minimally invasive and anatomical reconstruction.

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References

[1] Liu H, Xu S, Huang Z, et al. Application of Suspension Fixation with Button Plates for Patients with Distal Radioulnar Joint Dislocation: A Case Series[J]. Orthop Surg, 2021, 13(7): 2061-2069.
[2] O'Malley O, Brown OC, Duncan L, Cheung G, et al. Isolated volar dislocation of the distal radioulnar joint: a case series and systematic review[J]. Ann R Coll Surg Engl, 2023, 105(3): 196-202.
[3] Wang Kai, Zheng Yi, Zhou Lihui. Research progress of ulnar impaction syndrome [J]. Journal of Shenyang Medical College, 2024, 26(02): 200-203.
[4] Rodríguez-Merchán EC, Shojaie B, Kachooei AR. Distal Radioulnar Joint Instability: Diagnosis and Treatment[J]. Arch Bone Jt Surg, 2022, 10(1): 3-16.
[5] Jawed A, Ansari MT, Gupta V. TFCC injuries: How we treat[J]. J Clin Orthop Trauma, 2020,11(4): 570-579.
[6] Herzberg G, Burnier M, Nakamura T. Arthroscopic Anatomy of the TFCC with Relevance to Function and Pathology[J]. J Wrist Surg, 2021,10(6): 558-564.
[7] Flores DV, Umpire DF, Rakhra KS, et al. Distal Radioulnar Joint: Normal Anatomy, Imaging of Common Disorders, and Injury Classification[J]. Radiographics, 2023, 43(1): e220109.
[8] Dai Jianhua, Jin Yongxiang, Wang Hanyu et al. Treatment of distal radioulnar joint dislocation with Dai's manual reduction and "sandwich" therapy with crescent-shaped small splints and paper pads [J]. Chinese Folk Therapy, 2023, 31(24): 62-65.
[9] Dai Gorong, Huo Liwei, Chen Chuncheng et al. Experience of manual reduction and small splint fixation in the treatment of distal radioulnar joint dislocation [J]. Inner Mongolia Traditional Chinese Medicine, 2016, 35(08): 118-119.
[10] Matonis D, Wittel K, Wray A. Case Report of Distal Radioulnar Joint and Posterior Elbow Dislocation[J]. J Educ Teach Emerg Med, 2020, 5(4): V12-V14.
[11] Darrach W, Nolan W B, Eaton R G. Partial excision of lower shaft of ulna for deformity following Colles's fracture. 1913.[J]. Clinical Orthopaedics & Related Research, 1992, 57(275): 3.
[12] Yayac M, Padua FG, Banner L, et al. Treatment Outcomes in Patients Undergoing Surgical Treatment for Arthritis of the Distal Radioulnar Joint[J]. J Wrist Surg, 2020, 9(3): 230-234.
[13] Bell M J, Hill R J, Mcmurtry R Y. Ulnar impingement syndrome[J]. The Bone & Joint Journal, 1985, 67(1): 126-129.
[14] Poujade T, Balagué N, Beaulieu JY. Unipolar ulnar head replacement for treatment of post-Darrach procedure instability[J]. Hand Surg Rehabil, 2018, 37(4): 225-230.
[15] Munaretto N, Aibinder W, Moran S, et al. Sauve-Kapandji Remains a Viable Option for Distal Radioulnar Joint Dysfunction[J]. J Hand, 2022, 17(5): 963-968.
[16] Minami A, Iwasaki N, Ishikawa J, et al. Treatments of osteoarthritis of the distal radioulnar joint: long-term results of three procedures[J]. Hand Surg, 2005, 10(2-3): 243-248.
[17] Deneuville M, Germon C, Sturbois-Nachef N, et al. The Sauvé-Kapandji procedure for post-traumatic distal radio-ulnar arthrosis: Long-term results and analysis of risks factors for revision surgery[J]. Orthop Traumatol Surg Res, 2024, 110(2): 103562.
[18] Brunet P, Moineau G, Liot M, et al. Etude radioclinique de l'instabilité du moignon proximal de l'ulna après l'intervention de Sauvé-Kapandji pour séquelles post-traumatiques [Radiological and clinical study of the ulna's end instability after Sauvé-Kapandji procedure][J]. Chir Main, 2004, 23(4): 178-183.
[19] Sakamoto K. Treatment of Proximal Ulnar Stump after Darrach or Sauvé-Kapandji Procedure by Transfer of Insertion-Released Pronator Quadratus Pedicle[J]. Hand Surg Asian Pac Vol, 2021, 26(1): 70-76.
[20] Li Jianqiang, Xiao Peng. Modified Sauve-kapandji procedure combined with flexor carpi ulnosus fixation for distal radioulnar joint dislocation [J]. Chin J Orthopedics, 2019, 27(17): 1609-1611.
[21] Fang Yiyi, Zhao Wenzhi, Pan Deyue et al. Treatment of chronic dislocation of distal radioulnar joint with modified Sauve-Kapandji procedure: a case report [J]. J Practical Orthopedics, 2019, 25(12): 1147-1148.
[22] Chen Baicheng. Current status and prospect of clinical application of arthroscopy. China Bone Injuries, 2014, 27(08), 621-624.
[23] Herzberg G, Burnier M, Nakamura T. Arthroscopic Anatomy of the TFCC with Relevance to Function and Pathology[J]. J Wrist Surg, 2021, 10(6): 558-564.
[24] Palmer AK. Triangular fibrocartilage complex lesions: A classification[J]. The Journal of Hand Surgery, 1989, 14(4): 594-606.
[25] Cerezal L, Del Piñal F, Atzei A, et al. Interdisciplinary consensus statements on imaging of DRUJ instability and TFCC injuries[J]. Eur Radiol, 2023, 33(9): 6322-6338.
[26] Liang Kaixin, Gao Ze, Wang Junxuan, et al. Research progress of triangular fibrocartilage complex injury [J]. Chin J Orthopedics, 2023, 44(06): 345-348+357.
[27] Lu Chengyin, ZHANG Hailong, Zhang Laifu, et al. Anatomical repair of Atzei-EWAS type 2 triangular fibrocartilage

complex injury under wrist arthroscopy [J]. Chin J Prosthetics and Reconstructive Surgery, 2021, 35(11): 1417-1421.
[28] Tsai M, Lin YH, Chiu CH, et al. All-arthroscopic repair of Atzei class II and III triangular fibrocartilage complex tears using the FasT-Fix suture device[J]. J Orthop Surg Res, 2021, 16(1): 210.
[29] Atzei A, Luchetti R, Garagnani L. Classification of ulnar triangular fibrocartilage complex tears. A treatment algorithm for Palmer type IB tears[J]. J Hand Surg Eur Vol, 2017, 42(4): 405-414.
[30] Abe Y, Takahashi Y, Fujii K. Preliminary Report of Arthroscopically Assisted Sauvé-Kapandji Procedure for Distal Radioulnar Joint Arthritis[J]. J Wrist Surg, 2021, 10(3): 262-267.
[31] Kakar S, Carlsen BT, Moran SL, et al. The management of chronic distal radioulnar instability[J]. Hand Clin, 2010, 26(4): 517-528.
[32] Bai Wei-fei, YU Qian-qian, Jiang Yu-Chen, et al. A retrospective analysis of two surgical procedures for delayed dislocation of the distal radioulnar joint [J]. Chinese Journal of Bone and Joint Injury, 2018, 33(07): 766-768.
[33] Tang Zhao, BAO Ni-rong, WANG Bei-yue et al. Comparison of the early effect of loop plate and hollow screw fixation in the treatment of distal radioulnar joint dislocation [J]. Chin J Med Postgraduate, 2022, 35(04): 383-387.
[34] Adams BD, Lawler E. Chronic instability of the distal radioulnar joint[J]. J Am Acad Orthop Surg, 2007, 15(9): 571-575.
[35] Scheker LR, Scheker JM. The distal radio ulnar joint: a journey of discovery and invention of the Aptis prosthesis[J]. J Hand Surg Eur Vol, 2023, 48(6): 505-513.
[36] Scheker LR, Babb BA, Killion PE. Distal ulnar prosthetic replacement[J]. Orthop Clin North Am, 2001, 32(2): 365-x.
[37] Brannan PS, Ward WA, Gaston RG, et al. Two-Year Clinical and Radiographic Evaluation of Scheker Prosthesis (Aptis) Distal Radioulnar Joint Arthroplasty[J]. J Hand Surg Am, 2022, 47(3): 290.e1-290.e11.
[38] Levina Y, Mesa L, Hannon PJ, et al. Retrospective and Prospective Outcomes of Distal Radioulnar Joint Prosthesis Arthroplasty at a Single Center[J]. J Hand Surg Glob Online, 2023, 5(5): 620-623.
[39] Nguyen MH, Lipari N, O'Brien AL,et al. Darrach vs. Sauve-Kapandji: A Comprehensive Meta-Analysis of Surgical Outcomes in Distal Radioulnar Joint (DRUJ) Dysfunction[J]. Indian J Orthop, 2023, 57(4): 565-570.
[40] Mak MCK, Ho PC. Complications after arthroscopic triangular fibrocartilage complex (TFCC) surgery[J]. J Hand Surg Eur Vol, 2024, 49(2): 149-157.