ORIGINAL ARTICLE

Arthroscopic treatment with absorbable bone cement for intra-articular comminuted fracture of the distal radius

Tratamiento artroscópico con cemento óseo reabsorbible para la fractura intraarticular conminuta del radio distal

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Abstract

Objective: *The objective of this study was to explore the clinical application value of arthroscopic injection of absorbable calcium sulfate bone cement in the treatment of distal radius intra-articular comminuted fractures.* **Methods:** *A total of 15 patients with distal radius intra-articular comminuted fractures treated in the Department of Hand Surgery I of our hospital from January 2020 to October 2021 were selected as the research subjects, including nine males and six females, aged 25-55. Closed reduction was performed first, followed by arthroscopic-assisted fracture reduction to eliminate step-off caused by the fracture and to inspect and repair damaged ligaments. Absorbable bone cement was injected into the fracture gap under fluoroscopy or arthroscopic guidance. The Mayo wrist score and Gartland-Werley score were used to assess wrist pain and joint function of the patients.* **Results:** *In the latest follow-up, 12 cases achieved excellent results in the Mayo score, and three cases achieved good results; Gartland-Werley score: 11 cases were excellent, and 4 cases were good.* **Conclusions:** *Arthroscopic injection of calcium sulfate bone cement for distal radius intra-articular comminuted fractures is effective, with the advantages of minimal trauma, satisfactory reduction, fewer post-operative complications, and the ability for early functional exercise in patients.*

Keywords: *Wrist arthroscopy. Calcium sulfate bone cement. Distal radius intra-articular comminuted fracture. Traumatic arthritis.*

Resumen

Objetivo: *Explorar el valor clínico de la inyección artroscópica de cemento de sulfato de calcio reabsorbible en el tratamiento de la fractura conminutas intraarticular del radio distal.* **Métodos:** *Se seleccionaron 15 pacientes (9 hombres y 6 mujeres), de entre 25 y 55 años, con fractura conminuta intraarticular del radio distal tratados en nuestro hospital entre enero de 2020 y octubre de 2021. Primero se realiza una reducción cerrada y luego una reducción de fractura asistida por artroscopia para eliminar la dislocación causada por la fractura, examinar y reparar los ligamentos dañados. Bajo guía de fluoroscopia o artroscopia, el cemento óseo reabsorbible se inyecta en el espacio de fractura. Para evaluar el dolor de muñeca y la función articular del paciente se utilizaron la puntuación Mayo de muñeca y la puntuación de Gartland y Werley.* **Resultados:** *En el seguimiento reciente, 12 pacientes alcanzaron una excelente puntuación Mayo y 3 alcanzaron una buena puntuación de Gartland y Werley: 11 casos excelentes y 4 casos buenos.* **Conclusiones:** *La inyección de cemento óseo de sulfato de calcio bajo artroscopia es efectiva en el tratamiento de fracturas conminutas en la articulación del radio distal, con pocas complicaciones posoperatorias y ejercicio funcional temprano en los pacientes.*

Palabras clave: *Artroscopia de muñeca. Cemento de sulfato de calcio. Fractura conminuta intraarticular del radio distal. Artritis traumática.*

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Introduction

Distal radius fractures are the most common fractures in adults, with an incidence rate of 0.35%, and this rate is showing an upward trend.[1] These fractures are typically caused by high-energy trauma and can manifest as sheare, compression, burst, or avulsion fractures. In addition to osseous structural damage, they are often accompanied by carpal bone fractures.[2] Non-surgical treatment is suitable for stable fractures, whereas displaced or unstable fractures usually require surgical intervention to restore upper limb alignment, functionality, and prevent post-traumatic arthritis.[3,4] Currently, the use of the volar approach and volar locking plates for treating distal radius fractures has been widely accepted. Although it can address most extra-articular and simple intra-articular fractures, treating comminuted intra-articular fractures, such as AO type C fractures, remains a challenge in surgery. Harness pointed out that the unique anatomical structure of the distal radius fracture area with volar bone fragments makes it challenging to support the entire volar surface using standard plates for fixation, due to the proximity of the fracture line to the joint surface, presenting treatment difficulties.[5] For elderly individuals with accompanying osteoporosis, bone deficiency is also a factor that must be considered. Moreover, distal radius intra-articular fractures often involve damage to ligaments and other structures. Without timely intervention, post-operative chronic wrist pain or wrist instability might persist.[6] How to reduce intra-articular comminuted fractures and repair ligament damage are critical aspects of surgically treating intra-articular fractures, and the emphasis on anatomical reduction and early functional exercises in the context of accelerated recovery concepts places higher demands on surgical techniques.[7,8] From January 2020 to October 2021, our department utilized wrist arthroscopy in combination with calcium sulfate bone cement for the treatment of 15 patients with distal radius fractures and intra-articular comminuted fractures. The results are reported as follows.

Methods

General information

Between January 2020 and October 2021, 45 patients underwent surgery for distal radius intra-articular comminuted fractures in our trauma center. Retrospective study subjects were identified according to inclusion and exclusion criteria, and 15 patients were included in the study.

Inclusion criteria

- Age 18-65 years and met the diagnostic criteria for a distal radius fracture;
- AO type C fractures;
- Patient's informed consent and signed informed consent;
- Patients were treated with arthroscopic treatment with absorbable bone cement;
- A minimum follow-up of 12 months after surgery.

Excluded patients

- Patients with a history of wrist joint surgery;
- Lost to follow-up.

There were 9 males and 6 females, aged between 40 and 65 years. Causes of injury included falls in 12 cases and collisions in 3 cases. The fractures were classified according to the AO classification as follows: C1 in 4 cases, C2 in 10 cases, and C3 in 1 case. This study was approved by the Medical Research Ethics Board of blinded for review. All patients were informed in detail before surgery, and consent was obtained from both the patients and their families. All surgeries were performed by the author.

Surgical procedure

Patients were administered brachial plexus nerve block anesthesia and placed in a supine position. Closed reduction was performed initially, with traction and compression to achieve closed reduction, aiming to restore radial height and avoid ulnar deviation. Fracture alignment was corrected, and palmar tilt, ulnar variance, and rotational deformity were restored. The affected limb was placed in a wrist arthroscopy tower, providing 3-4 kg of traction force. Dry arthroscopy was used intraoperatively. Arthroscopy was used for exploration, primarily involving intra-articular fracture reduction to eliminate step-off caused by the fracture. Subsequently, the integrity of the triangular fibrocartilage complex (TFCC) and the lunate ligament was further examined. Any injuries were repaired under arthroscopy. Passive wrist joint movement and

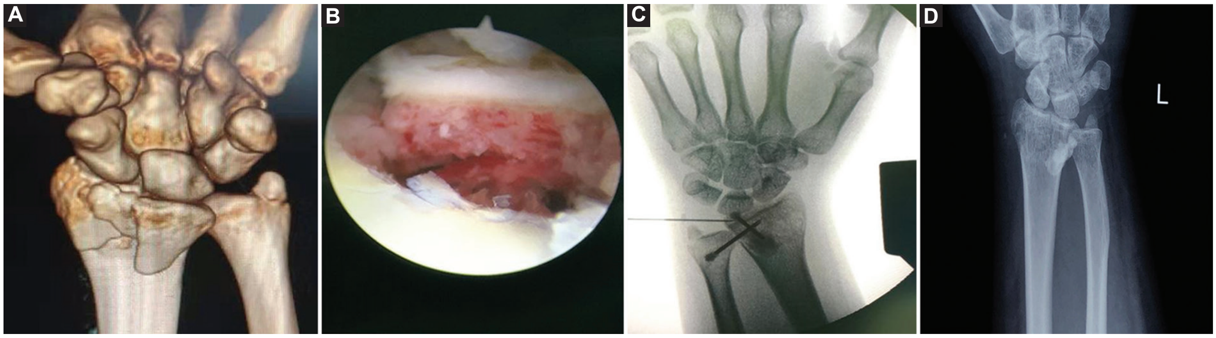

Figure 1. A: *patient, female, 34 years old, suffered from a left distal radius intra-articular fracture due to violence. The fracture was classified as AO type C3 with joint surface depression.* **B:** *under direct vision of wrist arthroscopy, articular surface fractures with step formation, triangular fibrocartilage complex (TFCC) injury, probe prying reduction, Kirschner wire fixation, reduction of articular surface, and repair of TFCC can be seen.* **C:** *post-operative fluoroscopy shows anatomical reduction of the joint surface, correction of ulnar variance angle, palmar tilt angle, and radial height. Injectable absorbable bone cement was injected into the fracture gap under fluoroscopic guidance.* **D:** *6 weeks after the operation, an X-ray of the wrist joint was taken. The fracture has basically healed, the articular surface has not collapsed, and the bone cement has been partially absorbed.*

ulnar-radial and radial-ulnar collision tests were performed during the surgery to assess joint stability. A Kirschner wire or cap screw was used for temporary intraoperative fixation. Once satisfactory exploration was achieved, the wrist joint was positioned under a fluoroscopy machine, and a needle was inserted into the fractured gap under fluoroscopy or arthroscopic guidance. Absorbable injectable calcium sulfate bone cement (STIMULAN, BIOCOMPOSITES, UK) was prepared with a ratio of 2 g calcium sulfate bone cement to 5 mL of normal saline using a 5 mL syringe. The cement was injected immediately and allowed to naturally solidify, with a solidification time of about 3 min. Postoperatively, the wrist joint was carefully immobilized in a plaster functional position.

Post-operative management and efficacy evaluation

Active and passive functional exercises for interphalangeal and metacarpophalangeal joints were initiated on the first day after surgery. At 3 weeks post-surgery, the plaster was removed, and patients were guided to perform passive wrist flexion-extension training. Resistance and weight-bearing training began at 4 weeks post-surgery. The Kirschner wire was pulled out at 4 weeks post-surgery. These patients began resistance and weight-bearing training at 6 weeks post-surgery.

Follow-up was conducted for at least 1 year. X-ray evaluation was performed to assess fracture healing and the occurrence of arthritis. General wrist conditions were assessed, including stability, range of motion, tendon irritation, wrist pain, and other complications. The Mayo wrist score and Gartland-Werley score were used to assess wrist pain and joint function.

Results

The average time from injury to operation was 3.5 days (range 2-7 days). All 15 patients in this group were successfully followed up, with a follow-up period ranging from 12 to 23 months, averaging 14.5 ± 4.1 months (Fig. 1). Two patients exhibited TFCC grade I injuries, which were cleaned and repaired intraoperatively. Two patients presented with injuries to the lunotriquetral ligament, which were managed through intraoperative fixation of the lunotriquetral joint. One patient experienced radial nerve symptoms 1 week after surgery, which disappeared after oral administration of methylcobalamin. Minimal cement leakage occurred in one case, requiring no specific treatment. All patients achieved anatomical restoration of the radiocarpal, radioulnar, and distal radioulnar joints. No complications such as infection, non-union, carpal tunnel syndrome, ulnar impaction syndrome, cement intolerance, or tendon rupture were observed.

Fracture healing time ranged from 8 to 15 weeks, with an average of 12.2 ± 2.7 weeks. The bone cement gradually absorbed around 4 weeks after surgery, with complete absorption occurring between 10 and 13 weeks, averaging 13.5 ± 1.9 weeks. At the latest follow-up, all patients exhibited stable wrist joints. Range of motion values were as follows: extension 36-45°, averaging 38 ± 3.5°; flexion 40-52°, averaging 45.2 ± 4.1°; pronation 65-80°, averaging 75.3 ± 5.3°;

supination 60-77°, averaging 69.1 ± 4.9°; palmar tilt angle 9-17°, averaging 12.5 ± 1.7°; ulnar variance angle 15-27°, averaging 22.5 ± 3.2°. In the latest follow-up, 12 cases achieved excellent results in the Mayo score, and 3 cases achieved good results. The Gartland-Werley score showed excellent results in 11 cases and good results in 4 cases.

Discussion

The distal radial articular surface is composed of different combinations of fracture fragments, including the radial column fragment, volar lip fragment of the lunate fossa, ulnar dorsal corner fragment, dorsal wall fragment, and intra-articular fragment. The specific location affected by distal radial fractures corresponds to the arrangement of these five fracture fragments. In addition, soft-tissue structures such as the radial collateral ligament, TFCC, and extensor carpi radialis brevis tendon are often damaged during traumatic events.[9,10] Achieving anatomical reduction is a treatment principle that can significantly reduce the risk of adverse effects such as traumatic arthritis.

Commonly used distal radius plates are volar plates. Soong reported that placing the distal radius plate at a 2nd position is necessary to fix fractures beyond the watershed line.[11] Traditional open surgery entails greater disruption and often requires incisions that sever the pronator quadratus muscle and involve traction of the median nerve. Fixation of dorsal fracture fragments may necessitate additional dorsal incisions, and exploring internal wrist joint structures can be challenging, particularly in cases of TFCC damage and injuries to the lunotriquetral ligament.[12-14]

The technique of arthroscopic-assisted injection of absorbable bone cement for fixation offers advantages such as minimal trauma, excellent outcomes, rapid recovery, and reduced discomfort.[15] Following reduction, step-off and fracture gaps on the joint surface should not exceed 1mm. Otherwise, residual wrist pain or functional impairment may occur postoperatively. However, it has been observed that fluoroscopy during surgery is often inadequate in detecting step-offs or gaps of around 1 mm.[15] Arthroscopy provides a direct view of fractures and soft-tissue injuries, allowing for direct repair of damaged joint surfaces and soft tissue structures. Yin et al.[10] used arthroscopy-assisted Kirschner wire fixation in combination with external fixation for treating fractures of the extreme distal radius in 21 patients. Intraoperative arthroscopy was utilized for initial exploration of the joint space, revealing TFCC tears in six cases. Arthroscopy can repair joint soft-tissue injuries and effectively address wrist joint dysfunction and persistent pain caused by soft-tissue damage.[10] In our study, two patients experienced TFCC injuries, and two patients had lunotriquetral ligament injuries, all of which were promptly repaired during surgery. Postoperative recovery met expectations, and no significant wrist pain was observed. Arthroscopy facilitates the removal of impurities such as blood clots and bone fragments from gaps while emphasizing the protection of damaged soft tissues. Anatomical reduction of the wrist joint surface was pursued during surgery, and arthroscopy holds unique advantages for certain fractures, such as those within the lunate fossa, dorsal wall fragments, and distal radioulnar joint fractures. In our procedures, we performed closed reduction, followed by meticulous arthroscopic repair and bone cement injection, striving to achieve maximal anatomical reduction. Adhesive fixation with bone cement can reduce the invasiveness of open surgery, aligning more closely with surgical principles[16] established in the field.

Subarticular bone defects often require bone grafting. Calcium sulfate bone cement material has good biocompatibility, degradability, and osteogenesis, and is widely used in the treatment of bone defects caused by vertebral compression fractures and trauma.[17] Calcium sulfate can produce a local micro-acid environment *in vivo*, which can increase the local calcium ion concentration, which is conducive to the aggregation and growth of osteoblasts. During the degradation and absorption, a large number of new bone trabeculae are formed, and the undegraded bone cement acts as a bone conduction scaffold. Bone cement absorption and bone tissue formation are synchronous, and the degradation and absorption rate of calcium sulfate is close to the rate of new bone formation.[18] Previous studies have shown that calcium sulfate bone cement can allow early wrist joint movement after the treatment of distal radius fractures, which can avoid wrist pain, stiffness, traumatic arthritis, and muscle atrophy caused by post-operative fixation, and has a good effect on comminuted fractures of the distal radius, unstable fractures, and osteoporotic fractures in the elderly. In addition, muscle contraction during early post-operative activity can produce axial stress at the fracture end, which can promote bone healing.[18] In this study, the minimally invasive injection method can effectively avoid periosteal injury and facilitate fracture healing. Calcium sulfate cement is used to fill bone defects, which is an important factor in restoring the articular surface and maintaining radial height. Calcium sulfate is acidic, which can increase the local calcium ion concentration and the activity of osteoblasts. At the same time, bone cement absorption and bone tissue formation are synchronized, and the degradation and absorption rate of calcium sulfate is close to the rate of new bone formation.[19] In this group of cases, the follow-up found that a small amount of bone cement leakage occurred in one case; without special treatment, the bone cement was gradually absorbed after about 4 weeks, and the average time of fracture healing was 13.5 ± 1.9 weeks. The fracture healing time was 8-15 weeks, the average time of fracture healing was 12.2 weeks, and the bone cement absorption and healing time were almost the same, which was basically consistent with the previous reports of healing time. This suggests that cement may not increase the risk of delayed union. The absorbability of bone cement could avoid secondary surgery, and all patients had no rejection reaction. After an average follow-up of 14.5 months, all patients had no chronic wrist pain or wrist arthritis, and wrist joint function recovered well. The authors used manual reduction, wrist arthroscopy, and the use of bone cement for injection to obtain reliable clinical results. Under the arthroscopic, the author examined and repaired TFCC injury, and used bone cement to repair the intra-articular steps and fill the bone defect. The combination of the three can effectively restore the length of the radius, fill the bone defect, and address the problem of articular surface reduction. Subarticular bone defects often require bone grafting. 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Early exercise is key to joint function recovery. Among the 15 cases in this group, active and passive flexion and extension exercises for the fingers and metacarpophalangeal joints were initiated 24 h post-operatively, whereas active wrist flexion, extension, and rotational exercises were started at 4 weeks post-operatively. No complications of refracture or deformity healing were observed. The surgical technique involving a plaster cast combined with injectable calcium sulfate bone cement not only met the requirements for anatomical reduction of fractures but also fulfilled the need for early rehabilitation exercises. During the procedure, the following points should be noted: (a) for cases where the central column fracture fragment of the radius cannot be reduced by flipping, Kirschner wires should be used to lever the fragment into position under arthroscopy; (b) as a supplementary material, bone cement can adhere to small bone fragments that are difficult to fix or free-floating fragments, such as smaller Die-punch fractures; (c) for cases involving ulnar styloid fractures, TFCC injuries are often present. After reduction, exploration of the TFCC injury can be conducted.

This study has several limitations: a limited number of cases. During the initial exploratory stage of surgery, the operation time was longer, and surgical techniques were less mature, which may have influenced post-operative recovery and data statistics. In addition, all surgeries were performed by one team of doctors, potentially introducing subjective factors influencing therapeutic outcomes. There is limited research on the optimal concentration ratio and injection timing of absorbable bone cement, and there is a lack of quantitative biomechanical studies.

Conclusions

Minimally invasive wrist joint surgery aligns with the concept of rapid recovery. It features small incisions and minimal tissue damage while serving both diagnostic and therapeutic purposes. This approach is particularly effective for repositioning joints with unique anatomical structures. The technique of injectable absorbable calcium sulfate bone cement provides a new perspective for surgeons in choosing treatment options. The combination of these two approaches serves as a beneficial supplement to traditional treatments, offering clinicians new avenues for therapy. In summary, the use of wrist arthroscopy combined with injectable calcium sulfate bone cement for treating distal radius intra-articular fractures results in minimal trauma, satisfactory reduction, and fewer post-operative complications. It allows patients to engage in early flexion-extension exercises, facilitating quicker restoration of wrist joint function.

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Conflicts of interest

The authors declare no conflicts of interest.

Ethical considerations

Protection of humans and animals. The authors declare that the procedures followed complied with the ethical standards of the responsible human experimentation committee and adhered to the World Medical Association and the Declaration of Helsinki. The procedures were approved by the institutional Ethics Committee.

Confidentiality, informed consent, and ethical approval. The authors have followed their institution's confidentiality protocols, obtained informed consent from all patients, and secured approval from the Ethics Committee. SAGER guidelines have been followed as applicable to the nature of the study. This study was approved by the Medical Research Ethics Board of Zhengzhou Orthopedic Hospital.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing or creation of the content of this manuscript.

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