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The Korean Fracture Society

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Aims and Scope

The Journal of Musculoskeletal Trauma is the official publication of the Korean Fracture Society. It is an international, peer-reviewed, open access journal dedicated to advancing the science, education, and clinical care of musculoskeletal trauma. The journal provides a platform for the dissemination of high-quality research, innovative techniques, and multidisciplinary approaches that improve patient outcomes in the field of orthopedic trauma and related disciplines.

As an open access journal, all articles are freely available to readers worldwide, ensuring the widest possible dissemination of knowledge and promoting collaboration among researchers, clinicians, and educators.

The scope of the journal encompasses the prevention, diagnosis, treatment, and rehabilitation of musculoskeletal injuries, including but not limited to:

- Fractures, dislocations, and soft tissue injuries of the extremities and axial skeleton
- Advances in surgical techniques, implants, and prosthetic devices
- Biomechanical and biological research related to trauma and tissue healing
- Rehabilitation strategies and innovations for functional recovery
- Clinical and translational research bridging basic science and clinical practice

The journal invites submissions of original research articles, systematic reviews, meta-analyses, technical notes, and correspondence that contribute to the advancement of musculoskeletal trauma care. Submissions are welcomed from all regions of the world, promoting a diverse and inclusive exchange of knowledge and perspectives.

The *Journal of Musculoskeletal Trauma* serves as a resource for orthopedic surgeons, trauma specialists, researchers, rehabilitation professionals, and all healthcare providers involved in the care of musculoskeletal injuries. By fostering collaboration and disseminating cutting-edge findings, the journal aims to elevate the standards of trauma care globally.

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The Korean Fracture Society
2F, 202-a5, 12-16, Dasanjungang-ro 146 beon-gil, Namyangju 12285, Korea
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A new milestone: launching the *Journal of Musculoskeletal Trauma* to foster global orthopaedic trauma collaboration

Kang-il Kim, MD, PhD[1,2]

[1]Korean Fracture Society, Seoul, Korea
[2]Department of Orthopedic Surgery, Kyung Hee University College of Medicine, Seoul, Korea

Dear esteemed colleagues and readers,

This year, the Korean Fracture Society proudly commemorates its 40th anniversary-a significant milestone underscoring our collective dedication to advancing the field of orthopedic trauma. Established in 1985, our society has evolved into a pivotal entity in musculoskeletal trauma research and education, making substantial contributions to improving patient outcomes both in Korea and globally.

To celebrate this landmark occasion, we are excited to announce the transition of our journal from the Korean-language *Journal of the Korean Fracture Society* to the English-language *Journal of Musculoskeletal Trauma* (JMT). This strategic evolution marks a deliberate initiative towards internationalization, driven by our desire to facilitate global collaboration, disseminate high-quality research, and address the dynamic needs of the global orthopedic trauma community.

Honoring Our Legacy, Embracing the Future

For decades, the *Journal of the Korean Fracture Society* served as a crucial platform for disseminating significant research findings and clinical insights among our members. While it played an essential role in enhancing the quality of orthopedic trauma care within Korea, the increasing globalization of scientific discourse necessitates broader accessibility and international reach. The transition to JMT reflects our commitment to these global demands, enabling our research to resonate across diverse cultural contexts and fostering cross-cultural academic exchanges.

JMT is not merely a rebranding; it represents a comprehensive redefinition of its scope and purpose. JMT is designed to function as a central hub for sharing innovative research, advanced techniques, and critical insights from distinguished experts in the field of orthopedic trauma worldwide. Through this transformation, we aspire to invite contributions from international authors and broaden our readership to include a variety of professionals engaged in musculoskeletal trauma.

A Platform for Innovation and Collaboration

Our vision for JMT is both ambitious and clear: to establish it as a leading publica-

Editorial

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Correspondence to:
Kang-il Kim, MD, PhD
Department of Orthopedic Surgery, Kyung Hee University College of Medicine, 26 Kyungheedae-ro, Dongdaemun-gu, Seoul 02447, Korea
Tel: +82-2-440-7000
Email: drkim@khu.ac.kr

tion in musculoskeletal trauma, characterized by the rigor and relevance of its content. The journal will encompass a wide range of topics, including fractures, dislocations, soft tissue injuries, emerging technologies in trauma management, and related basic research. Each issue will contain original research articles, comprehensive reviews, and evidence-based clinical studies addressing the complex challenges faced by clinicians and researchers.

Moreover, we perceive JMT as a conduit for interdisciplinary collaboration and regional engagement. We aim to cultivate a dynamic exchange of ideas, foster international partnerships, and inspire innovations that enhance patient care outcomes. By providing a rigorous, peer-reviewed platform, we encourage the global orthopedic community to engage with us, not only as readers but also as contributors and collaborative partners in this shared mission.

A Collective Effort

The realization of this vision is a testament to collective determination. I extend my heartfelt gratitude to all members of the Korean Fracture Society and the past presidents, whose unwavering commitment over these 40 years has brought us to this moment. I am particularly thankful to the editorial board for their expertise and dedication in shaping the direction of our journal.

I would also like to express my appreciation to the authors and reviewers who have contributed to our inaugural issue. Your contributions embody the spirit of innovation and collaboration that defines our field. As we progress, we invite researchers, educators, and clinicians from around the globe to share their discoveries and insights through JMT.

Looking Ahead

The launch of JMT marks not the end of our journey but the dawn of a new chapter. It symbolizes our aspiration to transcend geographical boundaries, unite the global orthopedic trauma community, and make meaningful contributions to the advancement of musculoskeletal trauma care.

As we embark on this new endeavor, I warmly invite you to join us as readers, authors, and collaborators. Together, let us build a legacy of excellence and innovation that transforms lives across all borders.

Thank you for your unwavering support, and welcome to JMT.

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Introducing the *Journal of Musculoskeletal Trauma*

Jae Ang Sim, MD, PhD

Editor-in-chief of Journal of Musculoskeletal Trauma
Department of Orthopedic Surgery, Gil Medical Center, Gachon University College of Medicine, Incheon, Korea

It is with great honor and heartfelt gratitude that we present this issue of the *Journal of the Korean Fracture Society*, marking a historic turning point in its legacy.

We extend our deepest appreciation to our readers who have supported our journal over the past 36 years and to the researchers whose invaluable contributions have advanced the field of musculoskeletal trauma. Your dedication has been the cornerstone of the journal's success and its role in fostering innovation in fracture treatment and management.

Since its foundation in 1988, the *Journal of The Korean Fracture Society* has been a vital platform for disseminating research and clinical insights on the diagnosis and treatment of musculoskeletal injuries in Korea. By publishing research in the Korean-language, the journal has enabled the local medical community to exchange knowledge and elevate treatment practices in musculoskeletal trauma. Recognized as a registered journal by the National Research Foundation of Korea since 2008, it has earned the trust of countless researchers and has become a cornerstone of Korean medical scholarship.

Today, we embark on a transformative journey with a new name: *Journal of Musculoskeletal Trauma*. This change represents more than a simple rebranding; it is a strategic leap toward global recognition and scholarly communication. By transitioning to an English-language journal, we aim to share Korea's groundbreaking research with a global audience, actively engaging with researchers worldwide and contributing to international advancements in musculoskeletal trauma. Our efforts to be listed in international indexing databases underscore our commitment to raising the journal's profile and enhancing its academic influence globally.

The *Journal of Musculoskeletal Trauma* will serve as a conduit for the global exchange of research on fractures and musculoskeletal injuries. Featuring the latest research trends and clinical advancements, it will foster international collaboration and contribute to the improvement of treatment practices worldwide. This new chapter represents a pivotal step in ensuring that the achievements of Korean researchers are recognized on the global stage, while simultaneously enriching the global academic community.

In this transition, we remain deeply committed to our roots. We will honor our historical legacy as a Korean-language journal while embracing the opportunities of an international platform. Our mission is to maintain academic depth and integrity while providing the latest research findings that resonate with both domestic and global audiences. We invite our readers and researchers to continue their valuable

Editorial

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Correspondence to:
Jae Ang Sim, MD, PhD
Department of Orthopedics Surgery, Gachon University Gil Medical Center, Gachon University College of Medicine, 21 Namdong-daero 774beon-gil, Namdong-gu, Incheon 21565, Korea
Tel: +82-32-460-3384
Email: sim_ja@gilhospital.com

contributions, as your support will be instrumental in shaping the journal's future.

We owe special thanks to the President of the Korean Fracture Society, whose visionary leadership and unwavering dedication have been pivotal in this transition. Your commitment has made this transformation seamless, enabling us to step confidently into the international academic arena.

Finally, we extend our heartfelt gratitude to the editorial board members who have worked tirelessly to bring this issue to fruition. Your efforts and passion will serve as the foundation for the journal's continued success. We look forward to your ongoing engagement and collaboration as we embark on this exciting new chapter together.

Thank you.

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Easily missed nondisplaced fractures accompanying complete fractures in the lower extremity and pelvis: a narrative review

Young-Chang Park, MD

Department of Orthopedic Surgery, Severance Hospital, Yonsei University College of Medicine, Seoul, Korea

Nondisplaced fractures accompanying complete fractures are often difficult to detect on plain radiographs or computed tomography scans, posing a diagnostic challenge. The diagnosis of these frequently overlooked injuries can be delayed, potentially leading to suboptimal patient outcomes. This review discusses four commonly missed fracture patterns in the lower extremity and pelvis, including posterior involvement in fragility fractures of the pelvis, intertrochanteric extensions in isolated greater trochanter fractures, ipsilateral femoral neck fractures in high energy femoral shaft fractures, and posterior malleolar fractures in distal spiral tibial shaft fractures. An accurate diagnosis of these accompanying nondisplaced fractures is critical for optimizing surgical outcomes. Surgeons should incorporate thorough preoperative evaluations into their clinical practice to facilitate early detection and appropriate treatment strategies. Prompt identification and comprehensive management remain essential for improving patient outcomes.

Keywords: Bone fractures; Pelvis; Lower extremity; Diagnostic imaging; Magnetic resonance imaging

Review Article

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Correspondence to:
Young-Chang Park, MD
Department of Orthopedic Surgery, Severance Hospital, Yonsei University College of Medicine, 50-1 Yonsei-ro, Seodaemun-gu, Seoul 03722, Korea
Tel: +82-2-2228-2189
Email: yc4508@yuhs.ac

Introduction

The successful management of fractures relies on multiple factors, with accurate diagnosis and thorough evaluation forming the cornerstone of effective treatment planning. The diagnostic process typically includes a detailed patient history, physical examination, plain radiographs, and computed tomography (CT) scans of the affected area. Despite these assessments, missed diagnoses remain a significant challenge in clinical practice, particularly in the case of nondisplaced fractures accompanying complete fractures.

Nondisplaced or occult fractures present unique diagnostic challenges, as incomplete fracture lines can be difficult to identify, even with CT imaging. Advanced imaging modalities, such as magnetic resonance imaging (MRI) or bone scintigraphy, are generally more effective in detecting these fractures, making their inclusion an important consideration in selected cases. The presence of an accompanying nondisplaced fracture alongside a complete fracture adds complexity to clinical evaluations and increases the risk of misdiagnosis. Delayed recognition of these fractures can significantly affect postoperative outcomes.

This review highlights four commonly overlooked fracture patterns in the lower extremity and pelvis, emphasizing the diagnostic challenges and discussing strategies for optimal management.

Fragility Fracture of the Pelvis Type I: Posterior Involvement

Fragility fractures of the pelvis (FFP) are commonly associated with low energy trauma in older adults, and their incidence continues to rise with the aging population [1,2]. In 2013, Rommens and Hofmann [1] introduced a comprehensive classification system for FFP, which remains widely utilized. This system categorizes FFP into four types: type I involves anterior lesions only; type II includes nondisplaced posterior lesions; type III involves displaced posterior lesions; and type IV features bilateral displaced posterior lesions. Typically, type I and type II fractures are managed nonsurgically, whereas type III and IV fractures require surgical intervention, provided the patient's overall condition permits [2-4].

Among the subtypes, FFP type II fractures are the most prevalent and are generally considered stable fractures [1]. These fractures are often successfully treated with conservative measures, including pain management and physiotherapy, allowing weight bearing as tolerated. However, surgical intervention should be considered if patients experience significant pain that prevents ambulation within several days [5]. Recent studies suggest that early surgical intervention, particularly percutaneous fixation, can alleviate pain, promote early mobilization, and enhance overall outcomes in type II fractures [3,5-8]. However, postoperative complications should also be carefully considered in elderly patients [9-12].

Radiographic assessment of FFP typically involves plain radiographs and CT imaging. However, nondisplaced sacral fractures, often involving osteoporotic cancellous bone, are difficult to identify with these modalities and are frequently overlooked [3,13]. Fractures initially classified as type I (anterior lesions only) are often reclassified as type II upon further evaluation with advanced imaging techniques such as MRI (Fig. 1). At our institution, MRI is considered for cases involving ambiguous sacral buckling, localized posterior pain during mobility, or significant difficulty walking due to pain after approximately 1 week of weight bearing as tolerated with a walker. Scheyerer et al. [14] reported that 96.8% of elderly patients with pubic rami fractures also had posterior lesions. Subtle findings, such as sacral buckling, may be more clearly visible on coronal CT images, aiding in diagnosis (Fig. 2). However, in patients with severe degenerative changes, bony spurs can mimic subtle buckling, complicating differentiation. Bilateral comparison of imaging findings can assist in resolving such ambiguities.

Given the structural integrity of the pelvic ring, anterior fractures, such as ramus fracture, often suggest the possibility of associated injuries to the posterior pelvic lesion. Therefore, clinicians should maintain a high index of suspicion for posterior pelvic lesions, particularly in FFP type I cases. Close monitoring and further evaluation, when warranted, are essential for accurate diagnosis and optimal management.

Isolated Greater Trochanteric Fracture: Intertrochanteric Extension

Isolated greater trochanteric (GT) fractures are among

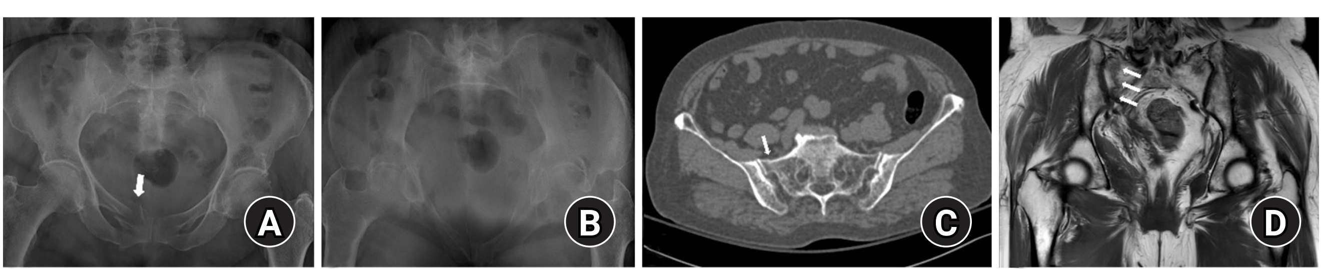

Fig. 1. A 78-year-old female patient with a fragility fracture of the pelvis due to a slip down injury. (A, B) Plain radiographs (anteroposterior and outlet views) show fractures of the right superior and inferior rami (arrow). (C) According to the Rommens classification, the fracture is categorized as type I based on a computed tomography evaluation, as no definite posterior involvement is observed; however, there is a suggestion of subtle buckling in the right sacral ala (arrow). (D) T1-weighted axial magnetic resonance imaging reveals posterior involvement (arrows), reclassifying the fracture from type I to type II.

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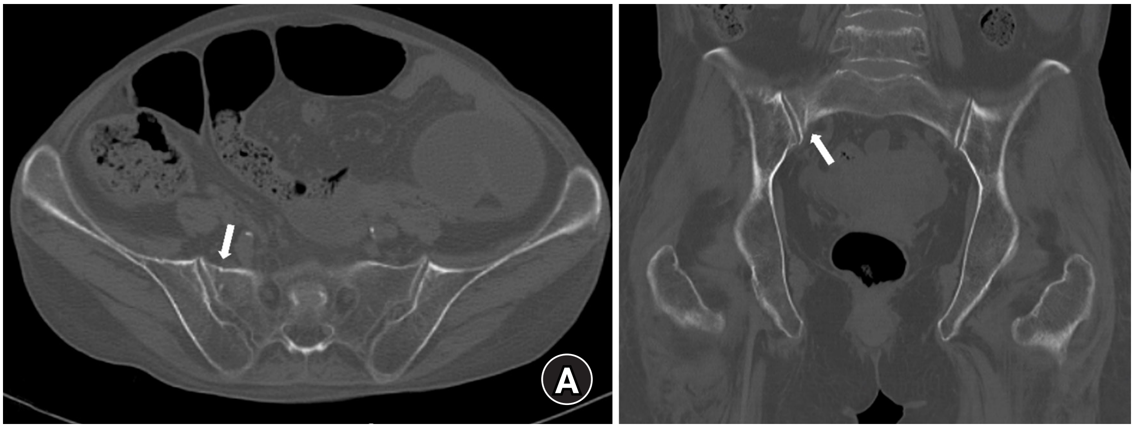

Fig. 2. Subtle buckling of the sacral ala. (A, B) Subtle buckling (arrows) is more clearly detected on coronal computed tomography images than on axial images.

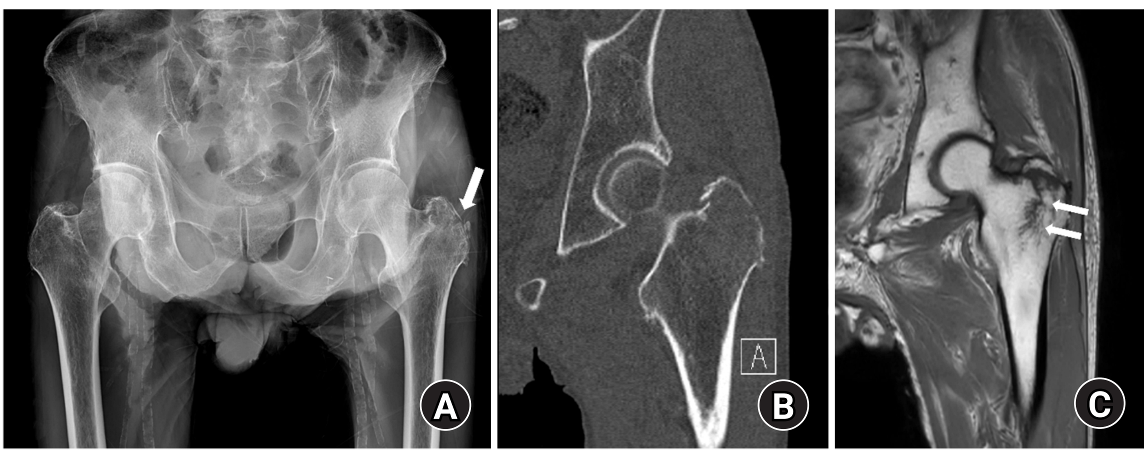

Fig. 3. A 78-year-old male patient with a greater trochanteric fracture due to a slip down injury. (A) A plain radiograph shows a left greater trochanteric fracture (arrow). (B) A computed tomography scan shows no specific findings. (C) T1-weighted midcoronal magnetic resonance imaging reveals intertrochanteric extension involving approximately 50% of the intertrochanteric line (arrows).

the rarest types of hip fractures and are typically managed with conservative treatment [15-18]. However, studies have shown that many fractures initially diagnosed as isolated GT fractures actually involve undetected intertrochanteric (IT) extension [17-20]. MRI is considered the gold standard for diagnosing IT extension, providing a more accurate assessment of the fracture and facilitating precise treatment planning (Fig. 3) [21-25] .

MRI not only enables the detection of IT extension but also helps determine its extent, allowing for the development of tailored treatment strategies. Arshad et al. [26] reported that fractures involving less than 50% of the IT line and forming an angle of 35°–42° relative to the vertical medial cortex were unlikely to progress to complete fractures. Park et al. [27] proposed using coronal T1-weighted MRI to divide the femoral canal at the lesser trochanter's upper level into thirds. Nonsurgical management was found effective for fractures confined to the lateral two-thirds, while surgical intervention was recommended for those involving the medial one-third or the medial cortex. Similarly, Kent et al. [28] supported nonsurgical management for fractures involving less than 50% of the IT line.

Currently, there is no definitive consensus on the surgical indications for isolated GT fractures, and the relative effectiveness of surgical versus nonsurgical treatment remains uncertain. Several studies highlight the use of institution-specific protocols to guide treatment decisions, with surgery being recommended primarily for high-risk

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patients based on arbitrarily defined criteria [26-30]. In Severance Hospital, conservative management is pursued for cases where neither the anterior nor medial cortex is involved. This approach includes pain management, hip range of motion exercises, and ambulation with weight bearing as tolerated. However, if conservative management proves intolerable, surgical treatment is considered to facilitate early ambulation. Patients managed nonoperatively are also informed about the potential risk of progression to a complete fracture.

MRI assessment of IT extension is invaluable in cases of isolated GT fractures initially diagnosed on plain radiographs. By identifying candidates for nonsurgical treatment, this approach supports more informed discussions with patients and enables individualized treatment planning tailored to fracture severity and patient needs.

High Energy Femoral Shaft Fracture: Ipsilateral Femoral Neck Fracture

Ipsilateral femoral neck fractures occur in approximately 9% of femoral shaft fractures [31-33]. Due to their nondisplaced nature, these fractures are challenging to detect, with 19%–55% remaining undiagnosed on plain radiographs, often resulting in delayed diagnoses [34,35]. Yang et al. [34] reported a detection rate of 63% for occult fractures using CT, while Tornetta et al. [36] introduced a protocol combining preoperative fine cut CT and immediate postoperative radiographs, reducing delayed diagnoses by 91%. Despite these efforts, the sensitivity of CT for detecting occult femoral neck fractures remains limited, ranging from 64% to 82% [37,38].

Alternative diagnostic and treatment approaches have been proposed to address this challenge. Routine fixation of the femoral neck during reconstruction nailing is one option; however, this method is associated with increased operative time, greater radiation exposure, and limited cost effectiveness [35]. Rogers et al. [39] highlighted the utility of rapid limited-sequence MRI, which detected occult femoral neck fractures in 12.1% of CT-negative cases. Park et al. [40,41] introduced the "CT capsular sign" as an indirect indicator of femoral neck fractures on abdomino-pelvic CT scans in trauma patients. This sign, characterized by capsular bulging due to lipohemarthrosis within the hip capsule, demonstrated 100% sensitivity for ruling out femoral neck fractures. Based on these findings, a protocol was proposed to perform preoperative MRI or prophylactic femoral neck fixation with reconstruction nailing when the CT capsular sign is positive (Fig. 4).

Delayed diagnosis of ipsilateral femoral neck fractures in the context of femoral shaft fractures can have devastating consequences, including unplanned surgeries, osteonecrosis, and nonunion [42,43]. For this reason, patients with high energy femoral shaft fractures require a heightened index of suspicion for associated femoral neck fractures. Thorough preoperative evaluation with X-rays and CT scans, including assessment for CT capsular signs, is essential. Advanced imaging modalities such as MRI should be selectively employed in cases where initial evaluations are inconclusive. Additionally, intraoperative or immediate postoperative internal rotation views should be obtained with the femur stabilized to minimize the risk of missed diagnoses. Incorporating these findings into diagnostic protocols may improve the detection and management of ipsilateral femoral neck fractures in high energy femoral shaft fractures.

Distal Spiral Tibial Shaft Fracture: Posterior Malleolar Fracture

Distal spiral tibial shaft fractures are relatively common in clinical practice and are frequently associated with posterior malleolar fractures, which occur in more than 90% of cases [44,45]. Previous studies have identified two key predictors of associated posterior malleolar fractures: a fracture obliquity angle greater than 45° and fracture extension into the distal one-third of the tibia [46,47]. Hou et al. [44] reported that a communication line between the main spiral fracture and the posterior malleolar fracture was identifiable in 92.1% of cases through detailed analysis of CT axial images.

Management of distal spiral tibial shaft fractures with concurrent posterior malleolar fractures can be achieved using either plating or nailing techniques. While plating is generally effective, nailing is often preferred in cases with soft tissue concerns or when the spiral fracture line is located at a higher level. When tibial nailing is planned, stabilizing the posterior malleolar fracture with percutaneous fixation beforehand is recommended, as intraoperative displacement of the posterior malleolar fracture has been

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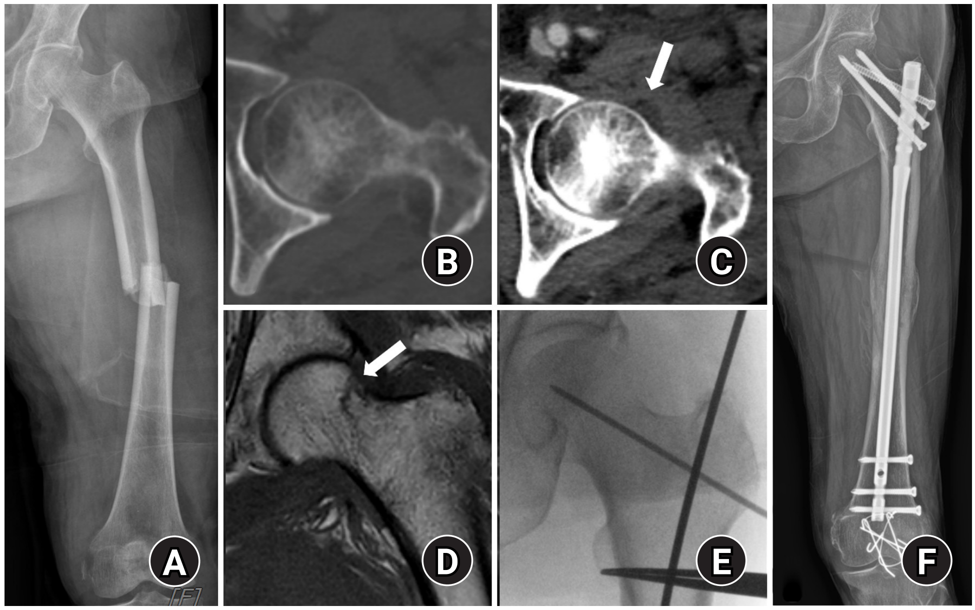

Fig. 4. A 70-year-old female patient with a femoral shaft fracture due to a motor vehicle accident. (A) Initial anteroposterior radiograph. (B, C) A preoperative bone-window computed tomography (CT) scan shows no femoral neck fracture; however, the soft-tissue-window CT scan reveals a positive CT capsular sign with lipohemarthrosis (arrow). (D) T1-weighted coronal magnetic resonance imaging reveals an incomplete ipsilateral femoral neck fracture (arrow). (E) An anterior provisional pin was inserted before nailing to prevent femoral neck displacement. (F) Uneventful bone healing was achieved at 10 months postoperatively.

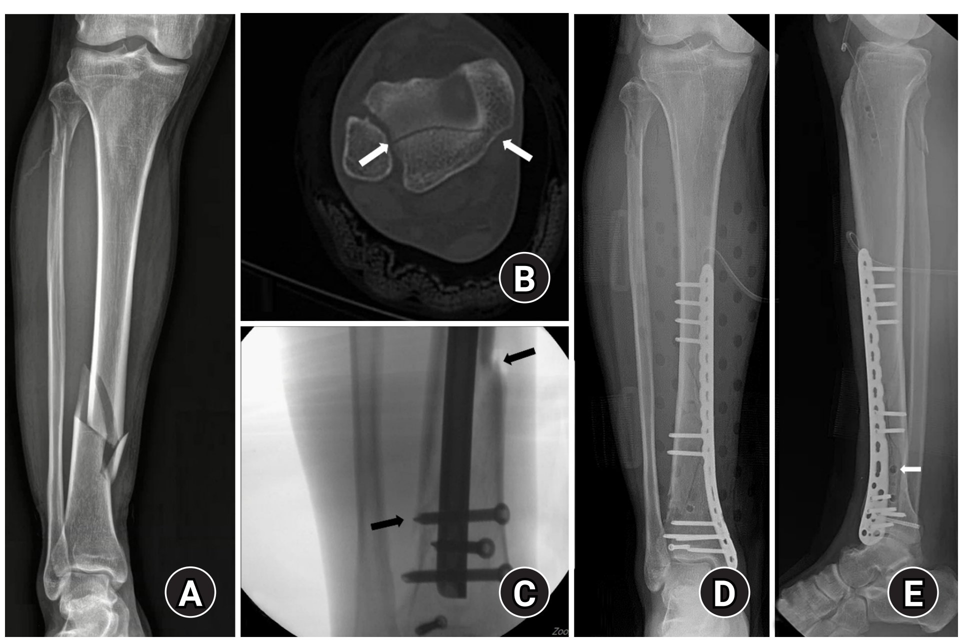

Fig. 5. A 52-year-old male patient with a distal spiral tibial shaft fracture and an associated posterior malleolar fracture. (A) Initial anteroposterior radiograph. (B) A preoperative computed tomography scan reveals the posterior malleolar fracture (arrows) with a communication line between the tibial shaft and the posterior malleolar fractures. (C) An intraoperative fluoroscopic image shows fracture displacement (arrows) after distal interlocking screws were placed, resulting in unstable fixation. Percutaneous fixation of the posterior malleolar fracture was performed prior to nailing. (D, E) Intraoperatively, nail removal and plate conversion were performed. Postoperative radiographs confirm the placement of the distal interlocking screw through the communication line (arrow).

observed in approximately 31% of cases during nailing procedures [48].

Special caution is required during distal interlocking fixation in tibial nailing, as inserting screws through the communication line may lead to malreduction or instability of the tibial fracture (Fig. 5). This highlights the critical importance of meticulous preoperative planning and precise intraoperative technique to optimize outcomes and minimize complications.

Conclusions

Nondisplaced fractures accompanying complete fractures in the lower extremity and pelvis frequently escape detection on conventional imaging, resulting in delayed diagnoses and suboptimal outcomes. In FFP, clinicians should remain vigilant for posterior lesions and ensure close monitoring. GT fractures require evaluation for IT extensions with mandatory MRI. High energy femoral shaft fractures demand assessment for ipsilateral femoral neck fractures, with the CT capsular sign serving as a valuable diagnostic tool. Distal tibial spiral fractures necessitate careful evaluation for posterior malleolar fractures and communication lines. Recognizing these easily overlooked injuries and implementing standardized clinical protocols that incorporate targeted diagnostic approaches is crucial. Early detection through comprehensive evaluation and individualized management strategies is essential for optimizing surgical outcomes and enhancing patient care.

Article Information

Author contributions

All the work was done by Young-Chang Park.

Conflict of interest

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Data availability

Not applicable.

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The clinical outcome of treating elderly distal radius fractures by long volar locking plate with the elimination of irreducible metaphyseal comminuted volar cortical fragments: a retrospective case series

Soo Min Cha, MD, PhD

Department of Orthopedic Surgery, Regional Rheumatoid and Degenerative Arthritis Center, Chungnam National University Hospital, Chungnam National University College of Medicine, Daejeon, Korea

Background: In severe comminuted metaphyseal distal radius fracture (DRF) of elderly patients, after maintaining only radiological parameters of the radius using long volar locking plates (VLPs), we inevitably eliminated a few volar cortical fragments of metaphysis. Here, we report the final radiological and clinical outcomes of our method.

Methods: For the patients who were treated between 2014 and 2018, the demographic factors, the preoperative radiologic factors, area of the eliminated volar cortical fragment, and final radiologic parameter, were evaluated. Clinical outcomes and ranges of active motion were evaluated.

Results: In total, 31 patients were included. The mean patient age was 77.3 years and the mean eliminated cortical area was 3.30 cm^2. At the final follow-up, the mean volar tilt, radial inclination, articular step-off, and ulnar variance were 10.35°, 20.00°, 0.58 mm, and 0.71 mm, respectively. There were no definitive correlations between bone mineral density, fragment area, the largest cortical fragment diameter ratio and differences in final and immediate postoperative measurements of these radiological parameters, respectively. Visual analog scale and disabilities of the arm, shoulder, and hand (DASH) scores were satisfactory, and the mean arcs of flexion-extension and pronation-supination were 124.35° and 133.23°. Clinical outcomes were not significantly different according to the AO system category.

Conclusions: For maintenance of radiological parameters of the radius, long VLPs are useful in older patients with DRFs who exhibit volar metaphyseal comminution, despite concurrent ulnar fractures. Inevitable elimination of irreducible free comminuted cortical fragments when filling the defect does not affect final radiological and clinical outcomes.

Level of evidence: Level IV, case series.

Keywords: Metaphysis; Comminuted fractures; Wrist fractures; Ulna

Original Article

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Correspondence to:
Soo Min Cha, MD, PhD
Department of Orthopedic Surgery, Chungnam National University College of Medicine, 266 Munhwa-ro, Jung-gu, Daejeon 35015, Korea
Tel: +82-42-280-7349
Email: smcha@cnu.ac.kr

Introduction

Distal radius fractures (DRFs) are the most common upper limb fractures, comprising more than 16% of all fractures [1]. However, it remains difficult to treat high-energy fractures of the distal radius involving both an intra-articular component and metaphyseal comminution with diaphyseal extension. Furthermore, this type of fracture occasionally occurs just after a simple slippage in elderly patients over 70 years. These fractures are difficult to manage partly because of specific biological and mechanical aspects that must be considered when treating intra-articular fractures with proximal extension. Volar locking plates (VLPs) have been designed with longer shapes to cover more proximal metaphysis and diaphysis. These plates are considered useful for the management of volar comminuted fractures of the distal radius, which involve proximal extension into the diaphysis, and with their use, the complications of external fixation or dorsal bridging of distraction plates can be avoided or minimized [2,3].

On the other hand, a few fracture fragments have been considered essential for proper union in several anatomical areas of among the overall skeleton, such as the medial calcar fragments in the proximal humerus or femur [4-6]. Since the development of locking plates/screws and their implementation worldwide, the AO principle has been used to investigate several mechanical and biological aspects of comminuted fragment healing [4]. The principle also suggests placement of the plate on the bony surface under conditions of distractive force. However, in older patients with low bone mineral density (BMD), low-energy injuries occasionally result in severe comminuted metaphyseal DRFs. Furthermore, it could be extremely difficult to fix and maintain for each volar fragment with long VLP.

In particular, for the maintenance of the radial length during plating and surgical manipulations (e.g., distal traction), a few free fragments never contact with other fragments, inevitably. Thus, we hypothesized the inevitable elimination for these irreducible fragments of volar cortex with comminution would not affect the final outcomes, if the radiological parameters of the radius were restored using long VLPs. Here, we report the final radiological and clinical outcomes of this procedure after at least 2 years of follow-up, along with factors that may influence these outcomes.

Methods

Ethics Statement

The study was approved by the Institutional Review Board of Chungnam National University Hospital (IRB No. 2021-09-056) and performed in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained.

Patient Selection

We retrospectively analysed patients who had been diagnosed with DRFs at Chungnam National University Hospital between March 2014 and September 2018. Among 522 patients screened for analysis, 34 were included in the study. Patients were selected based on the following criteria: (1) age >70 years; (2) independent living before injury; (3) the presence of irreducible comminuted volar fragments at distal metaphysis or diaphysis (at least 0.5×0.5 cm^2); (4) fixation with a long VLP for DRF with the inevitable elimination of one or more cortical fragments; (5) the presence of preoperative three-dimensional computed tomography (3D CT) images for the evaluation of fragment size; and (6) the availability of complete medical records and radiological data for at least 2 years postoperatively.

The exclusion criteria were (1) unstable concurrent ulnar fracture [7,8]; (2) other ipsilateral upper extremity injuries; (3) previous history of DRF treatment with conservative or surgical methods; (4) multiple comorbidities (i.e., >3 chronic diseases requiring medication); (5) history of trauma in the same wrist and/or neurological involvement; (6) atypical forearm fracture or administration of high-dose bisphosphonate as adjuvant chemotherapy for malignancy (e.g., breast cancer or multiple myeloma) [9,10]; (7) presence of symptomatic arthritis in the distal radioulnar joint at the time of surgery; and/or (8) comorbid autoimmune connective tissue disease requiring long-term steroid therapy.

Demographic and Clinical Characteristics

Demographic factors were evaluated, including age, sex, smoking status, comorbidities (diabetes or other medical diseases) and BMD. In particular, BMD was measured at the time of diagnosis of osteoporosis and atypical fracture using a Lunar Prodigy dual-energy X-ray absorptiometry instrument (GE Medical Systems) with enCORE ver. 8.8 (GE Medical Systems). Mean score values from the hip and spine were recorded. The lowest T score for the proximal femur and lumbar spine, except for the Ward area of the proximal femur, was recorded. We reported the level of expertise of the two surgeons as “Level 4/highly experienced category” for surgical practices [11].

Fracture Classification and Measurement of Eliminated Segment Size

Preoperative radiographs (anteroposterior, lateral, and

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oblique) and 3D CT images were evaluated to identify the number of articular fragments and the extent of comminution. Fractures were classified using the AO system [7]. First, the eliminated cortical segment area was measured based on picture archiving and communication system (PACS) software (m-view 5.4; Marosis Technologies Inc.). The fragment area was calculated automatically with the PACS software using the region-of-interest tool (Fig. 1). Furthermore, the widest fragment diameter was measured intraoperatively and the corresponding radius diameter at the fragment location was measured concurrently. Finally, the ratio of the fragment diameter to the radial metaphysis/shaft diameter was evaluated.

Classification of Ulnar Fractures

Any concurrent distal ulnar fracture was classified using the Q modifier, where Q1 indicates fracture of the ulnar styloid at its base, Q2 indicates simple fracture of the ulnar neck, Q3 indicates comminuted fracture of the ulnar neck, Q4 indicates fracture of the ulnar head, and Q5 indicates fracture of the ulnar head and neck [7]. Unstable ulnar fractures of this area, despite reduction and internal fixation of the radius, were characterized by two factors determined intraoperatively: malalignment and instability [7,8]. Malalignment was arbitrarily defined as >10° angular deformity. Instability of the ulnar fracture after the distal radius had been realigned and fixed was defined as the tendency for fracture fragments to move relative to one another (>50% translation) with passive forearm rotation. Ulnar fractures that met these two criteria were considered unstable and thus, excluded in this study [7,8].

Surgical Treatment and Postoperative Management

The procedure was done with the patient in the supine

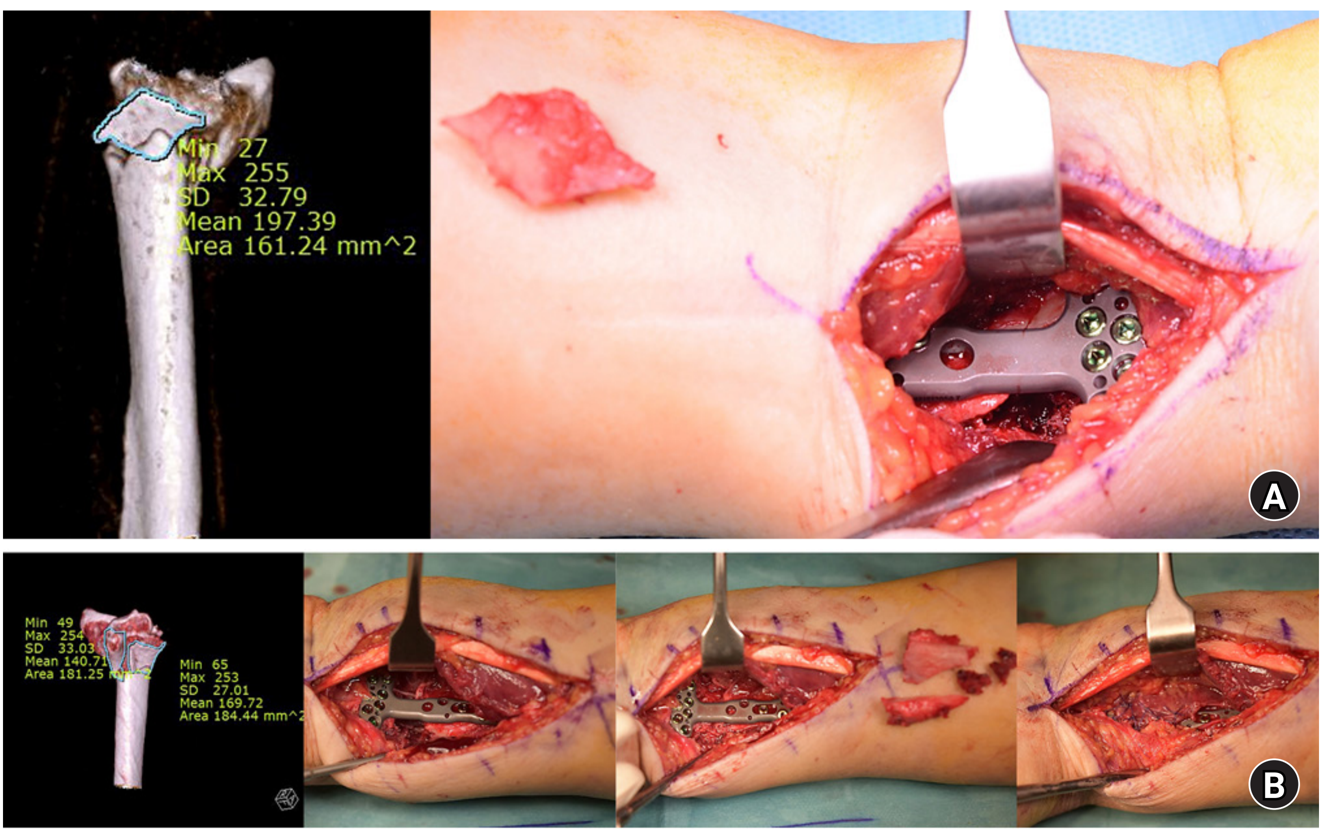

Fig. 1. (A) A 73-year-old woman was injured during a fall. A volar cortical metaphyseal fragment with an area of 1.61 cm^2 was removed during plating. The defect was filled with demineralized bone matrix. (B) A 78-year-old woman was injured. Two main volar cortical fragments with areas of 1.81 and 1.84 cm^2 were removed, and the defects were filled by morselized cancellous bone attached to the corresponding cortex. Min, minimum; Max, maximum; SD, standard deviation.

position on a radiolucent operating table. A longitudinal incision was made slightly radial to the flexor carpi radialis (FCR). Dissection was implemented between the radial artery and FCR. The pronator quadratus was then detached. The incision was extended proximally, depending on the fracture pattern and plate length, along the radial border of the FCR. The fracture site was exposed, and the hematoma was removed by rongeur and curettage. By means of ligamentotaxis with gentle finger traction, metaphyseal comminution was roughly and provisionally reduced with minimal manipulation. Traction was then applied, under fluoroscopic inspection, to determine the initial radial length. Then, cortical screws were fixed in proximal holes until proper compression could be achieved on the volar surface of the radius. Being pulled by assistant orthopedic surgeon, one or two distal locking screws were fixed after confirmation of radial length. During these distal fixations, areas with less comminution were fixed first, if possible, to preserve radial length. Unreducible volar free cortical fragments were then removed (Fig. 1). In a few patients with intra-articular DRFs, articular step-off was resolved by manipulation using a small elevator through the window of the original fragment location (Fig. 2). Following fixation of other locking screws in the distal area, final proximal locking screws were inserted. No concurrent ulnar fractures were fixed surgically. After surgery, the wrist was immobilized in a long-arm splint. Active digit range of motion exercises commenced immediately postoperatively. At 3 weeks postoperatively, the wrist was placed in a short-arm cast for an additional 3 weeks; physiotherapy (active and passive wrist mobilization without the cast) commenced at 6 weeks postoperatively.

Fig. 2. Intra-articular displacement was manipulated and reduced in the subchondral area through the window generated by the removed volar cortical fragment.

Radiological Evaluation

Radiological assessments were performed monthly for 3 months after surgery, then at 3-month intervals for 1 year. A final evaluation was conducted at least 2 years after the surgery. Fracture union was defined as >3 regions of bone bridging among the radial, ulnar, dorsal and volar cortical aspects of the distal part of the radius, as observed on anteroposterior, lateral and both oblique projections. Radiographic alignment was characterized by measurements of volar tilt, radial inclination, articular step-off and ulnar variance using standard measurement techniques [12]. The extra-articular type was defined as a 0-mm step-off. Immediate postoperative measurements and final follow-up measurements were compared. All radiological images were evaluated twice by two orthopedic surgeons not involved in the surgeries, with a 1-day interval between evaluations.

Clinical Outcomes

Clinical outcomes were compared between groups at the final follow-up. Data were collected by an independent observer (an orthopedic surgeon) who was not an author of this study. The clinical outcomes were the visual analog scale (VAS) postoperative pain score, the disabilities of the arm, shoulder, and hand (DASH) score, and ranges of active motion. A score of 0 on the VAS indicated no pain, and a score of 10 indicated extreme pain. DASH is a 30-item questionnaire that evaluates limitations with respect to the performance of daily activities, including leisure (four items) and work (four items). Total scores range from 0 to 100. Active motion of the wrist joint was measured using a standardized technique, in which a goniometer was placed dorsally and laterally.

Inter- and Intraobserver Reliabilities of Radiological Measurements

Intraclass correlation coefficients of continuous variables were used as indices of inter- and intraobserver reliabilities [13]. Kappa values were calculated for categorical variables,

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such as fracture type [14], using Fleiss and Cohen's ranges of >0.75, 0.40–0.75, and <0.40 to indicate excellent, good, and poor outcomes, respectively.

Statistical Analysis

The optimal sample size was calculated based on expected differences in the DASH score. Power analysis revealed that at least 23 patients were needed to detect a minimum difference in DASH score of 15 points between the two groups, with 20% assumed to be lost to follow-up, a type I error rate of 0.05, and a power of 0.8. These values are similar to those reported by Cha et al. [15] and Beaton et al. [16]. Associations of BMD, fragment area, and diameter ratio with final radiological outcomes were analysed using Pearson correlation. Categorical variables, such as AO classification and ulnar fracture pattern, were analysed using one-way analysis of variance or Scheffé post-hoc analysis to investigate associations with clinical outcomes. Sample size was calculated using G* Power ver. 3.1.9.2 (Heinrich-Heine-Universität Düsseldorf). All data were analysed using IBM SPSS ver. 22.0 (IBM Corp.). In all analyses, P<0.05 was considered to indicate statistical significance.

Results

In total, 31 patients were included in the analysis. The mean patient age was 77.3±4.9 years and the mean eliminated fragment area was 3.30±0.68 cm^2. At the final follow-up, the mean volar tilt, radial inclination, articular step-off, and ulnar variance were 10.35°±1.11°, 20.00°±0.97°, 0.58±0.62 mm, and 0.71±0.82 mm, respectively (Table 1). There were no definitive correlations between BMD, fragment area, largest fragment diameter ratio, and differences in the final and immediate postoperative measurements of these radiological parameters, respectively (Table 2). According to the fragment size, there were no differences of bony union at postoperative 3 and 6 months (Table 3). Furthermore, clinical outcomes in terms of VAS and DASH scores were satisfactory (0.23±0.43 and 6.41±2.38, respectively), and the mean arcs of flexion-extension and pronation-supination were 124.35°±8.34° and 133.23°±8.22°, respectively. Clinical outcomes were not significantly different according to the AO system category (Table 4). Finally, with the exception of the pronation-supination arc, there were no significant differences among types of concurrent ulnar fracture (Table 5).

In terms of radiological measurements, both inter- and intraobserver intraclass correlation coefficients indicated

Table 1. Basic demographic, radiological and clinical data

Variable	Value
Age (yr)	77.3±4.9
Sex (male:female)	11:20
Smoking (yes:no)	7:24
Comorbidity (yes:no)	16:15
Bone mineral density	−2.60±0.46
AO classification (A3.3:C2.2:C2.3:C3.3)	10:6:9:6
Area of eliminated fragment (cm^2)	3.30±0.68
Ratio of largest diameter of eliminated fragment	0.40±0.15
Ulnar fracture pattern (Q1:Q2:Q3:Q4:Q5:Q6)	0:8:7:11:2:3
Volar tilt at just after surgery (°)	10.52±1.06
Radial inclination just after surgery (°)	20.29±0.82
Articular step-off just after surgery (mm)	0.48±0.51
Ulnar variances just after surgery (mm)	0.55±0.77
Follow-up period (mo), median (range)	26.16±1.97 (24–32)
Volar tilt at final follow-up (°)	10.35±1.11
Radial inclination at final follow-up (°)	20.00±0.97
Articular step-off at final follow-up (mm)	0.58±0.62
Ulnar variances at final follow-up (mm)	0.71±0.82
Visual analog scale	0.23±0.43
DASH score	6.41±2.38
Flexion-extension arc (°)	124.35±8.34
Pronation-supination arc (°)	133.23±8.22

Values are presented as mean±standard deviation unless otherwise indicated.
DASH, disabilities of the arm, shoulder, and hand.

Table 2. Correlations between the clinical factors and radiologic outcomes

Difference between at final and just after surgery	Bone mineral density		Area of eliminated cortical fragment		Ratio of diameter	
	r	P-value	r	P-value	r	P-value
Volar tilt	−0.06	0.73	−0.03	0.88	0.07	0.70
Radial inclination	−0.43	0.11	−0.17	0.36	0.02	0.89
Articular step-off	0.24	0.19	0.03	0.86	0.14	0.45
Ulnar variances	−0.06	0.77	−0.13	0.47	0.10	0.59

Table 3. Differences of the union degree according to the area of eliminated cortical fragment

Area of eliminated cortical fragment	Union at postoperative (partial:full)		χ^2	P-value
	3 mo	6 mo		
<3.30±0.68 cm^2	2:10	0:12	0.63	0.507
>3.30±0.68 cm^2	2:17	0:19		

Table 4. Clinical outcomes according to the AO classification

Variable	AO classification	No.	Mean±SD	P-value
Visual analog scale	A3.3	10	0.20±0.42	0.92
	C2.2	6	0.17±0.41	
	C2.3	9	0.22±0.44	
	C3.3	6	0.33±0.52	
DASH score	A3.3	10	6.76±2.62	0.20
	C2.2	6	4.72±1.21	
	C2.3	9	6.38±2.30	
	C3.3	6	7.57±2.51	
Flexion-extension arc (°)	A3.3	10	128.00±7.89	0.38
	C2.2	6	120.83±6.65	
	C2.3	9	123.33±9.68	
	C3.3	6	123.33±8.16	
Pronation-supination arc (°)	A3.3	10	133.00±9.49	0.63
	C2.2	6	135.00±8.37	
	C2.3	9	130.56±8.08	
	C3.3	6	135.83±6.65	

SD, standard deviation; DASH, disabilities of the arm, shoulder, and hand.

Table 5. Clinical outcomes according to the ulnar fracture type

Variable	Ulnar fracture	No.	Mean±SD	P-value
Visual analog scale	Q1	8	0.12±0.35	0.49
	Q2	7	0.43±0.53	
	Q3	11	0.27±0.47	
	Q4	2	0.00±0.00	
	Q5	3	0.00±0.00	
DASH score	Q1	8	5.48±1.73	0.14
	Q2	7	8.08±2.35	
	Q3	11	6.68±2.58	
	Q4	2	5.58±3.08	
	Q5	3	4.59±0.50	
Flexion-extension arc (°)	Q1	8	120.62±10.84	0.08
	Q2	7	126.43±6.27	
	Q3	11	127.27±6.47	
	Q4	2	130.00±0.00	
	Q5	3	115.00±5.00	
Pronation-supination arc (°)[a]	Q1	8	138.75±3.54	<0.001
	Q2	7	134.29±5.35	
	Q3	11	135.00±5.92	
	Q4	2	117.50±10.61	
	Q5	3	120.00±0.00	

SD, standard deviation; DASH, disabilities of the arm, shoulder, and hand.
[a]Post-hoc: Q1, Q2, Q3>Q4, Q5.

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high reproducibility [13]. The κ-values of the category classification of the AO system and ulnar fractures were 0.89 and 0.85, respectively [14].

Discussion

There were some particular points for treatment of DRFs with volar metaphyseal cortical comminution for elderly patients, compared for fracture healing of the ordinary long bone through the well-established guideline of traumatology (AO principle). First, management of this injury requires basic knowledge concerning the distal one-third of the antebrachium and wrist. Furthermore, the metaphysis in DRFs in older patients exhibits further comminution, osteoporotic features, and concurrent dorsal cortex fragments, compared with ordinary long bone fractures [17,18]. Thus, the concepts of lag screw and compressive fixation for inter-segmental or butterfly fragments are difficult to apply. Second, VLPs have been established as an excellent option for a few decades and are associated with minimal complications. In particular, both fixed- and variable-angle VLPs have been used for the fixation of DRF fragments. Therefore, osteoporotic bones can be firmly secured by at least three-fourths of the distal locking screw length, considering the distance from the volar to dorsal cortex [19]. Furthermore, a distally angulated plate design of approximately 10° in the sagittal plane is essential for the restoration of volar tilt for radiocarpal articular surface by simple plating on the volar surface. To our knowledge, there have been no specific options for the fixture of metaphyseal comminuted DRFs, except for long VLPs marketed by several companies. Accordingly, long dorsal plating (bridging plate) under distractive conditions satisfies the AO principle, but has minimal supporting clinical evidence in this context [20-22]. Finally, the values of volar metaphyseal fragments should be estimated in a manner that differs from those of medial calcar fragments in the proximal humerus and femur. Indeed, the thickness and size of these fragments could be critical for fracture healing. However, precise and anatomical reduction with specific fragment geometry is difficult and can be more problematic in terms of radial length maintenance. Therefore, we first focused on length maintenance, then eliminated the resulting free volar cortical fragments, inevitably.

However, one aspect was consistent with the AO principle with the current surgical procedure. Because fragments were removed inevitably, rather than because of failure during attempted reduction, there was minimal manipulation of the metaphysis. Thus, the overall operation time was similar to that of ordinary DRFs. A minimally invasive method was described by Wei et al. [3], which was very similar to our approach in terms of hypothesis, treatment rationale and outcomes, although it involved preservation of the pronator quadratus. However, considering the basic demographic data and surgical method in the study, Wei et al. [3] inserted screws only in the most distal rows of distal plate areas. Furthermore, their degrees of comminution and displacement of articular fragments were somewhat less complicated than in our study, so the minimally invasive method may be suitable for some patients. In many of our patients, the comminution around articular area and the articular displacement were definitive, such that fragments reduction and plating were difficult to achieve while preserving the pronator quadratus. In a few patients, articular displacement was manipulated through the window made by comminuted proximal metaphysis fragments, after incision of the pronator quadratus (Fig. 2).

Although final solid union was achieved, all patients were informed that the VLP should not be removed during the follow-up period, if possible. When necessary, the reasons for removal were median nerve irritation, tendon-related concerns and procedures such as wrist fusion [19,23-27]. Among these, tendon-related concerns were the only risks that could be minimized during plating. Thus, the distal margin of the plate was adjusted to be categorized as "Soong grade 0 or 1" to reduce the risk of flexor attrition [26], and all distal screws were inserted 2–3 mm shorter than the distance to the dorsal cortex for patients with extensor problems (Fig. 3). As expected, the area from which the eliminated cortical fragment had been removed was considered a definitive defect at the final follow-up. However, no patient symptoms or signs merited plate removal.

We filled defects caused by cortical fragment elimination with either a morselized cancellous graft from the removed fragment, tricalcium phosphate or demineralized bone matrix. If there were little amount of cancellous bone attached to the cortical fragment, we added synthetic material if the patient agreed, due to its high cost. At the final follow-up, all fractures had healed with various types of cortical defects present in simple radiographs without any

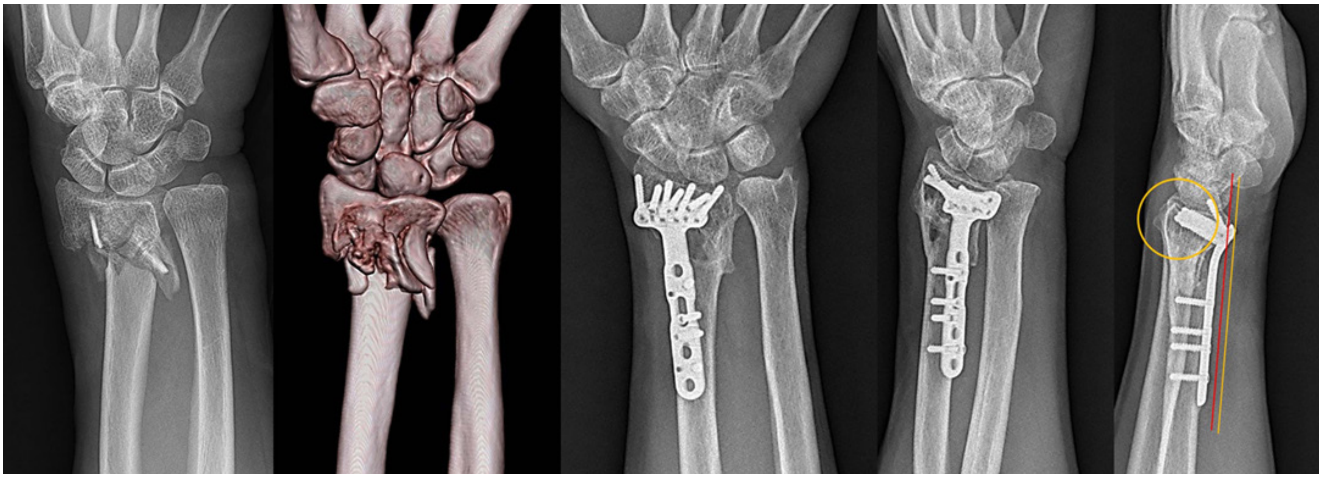

Fig. 3. A3.3 distal radius fracture with multiple comminuted metaphysis. At the final follow-up, the volar tilt and radial inclination was 9° and 20°, respectively, with the plate position of Soong grade 1. The lengths of the distal screws were approximately two-thirds distance from the volar to dorsal surface.

signs of non-union, radial shortening or metal breakage (Fig. 4). Although there have been a few comparative studies of materials used to fill comminuted radii in humans [28-30], long VLPs can guarantee the restoration of radiological parameters immediately after surgery, regardless of residual metaphyseal defects.

In all patients, concurrent ulnar fractures were treated conservatively in this study. Because many studies have been performed concerning ulnar styloid fractures in DRFs without distal radioulnar joint instability, there is a decreasing need for fixation, especially in older patients [31,32]. In this study, a few cases of styloid non-union (Q1) did not affect the final clinical outcomes (Table 5). Furthermore, the head, neck and metaphysis healed after radius union, following firm VLP fixation. Decisions for conservative treatment of these types of concurrent ulnar fractures, was based on also the several reports since 2010 [33,34], thus all concurrent head, neck and metaphyseal ulnar fractures exhibited satisfactory union in this study (Fig. 5). Patients with Q4 and Q5 ulnar fractures exhibited slight reductions in their pronation-supination arcs, but their daily activities were not limited, and the overall VAS and DASH scores were satisfactory for these patients.

Considering the clinical evaluation, there are two important points related to the older age of our patients. First, some patients had advanced arthritic changes in the radiocarpal joint at the final follow-up, compared with the time of injury. However, their clinical statuses were not

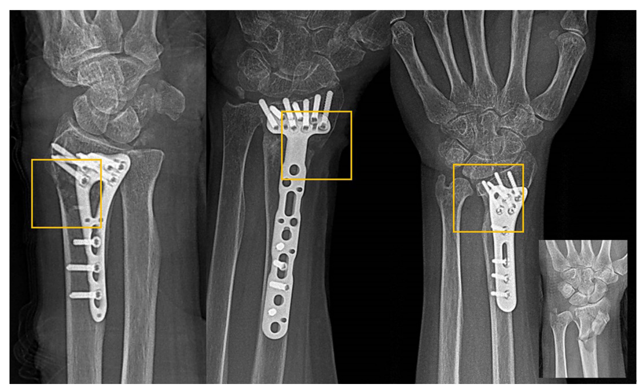

Fig. 4. Cortical defects identified in three patients. Mechanical support from long volar locking plates ensured volar cortex stability.

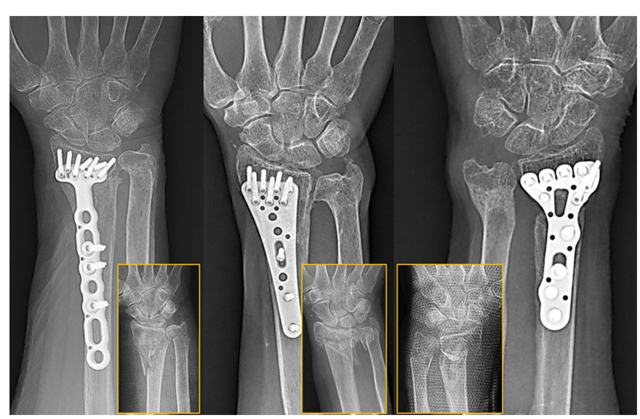

Fig. 5. With the exception of ulnar styloid fractures, satisfactory union at the final follow-up was observed for other types of concurrent ulnar fractures.

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compromised. Second, DASH scores revealed incomplete recovery, but the patients' subjective conditions (including VAS scores) were satisfactory. We presume that these were because most older patients had previously adjusted to physical conditions appropriate for their age, and because of aging-related reductions in demands on the upper extremities [33].

This study had some limitations. First, it was not a comparative trial. Comparisons among patient groups with similar characteristics (e.g., age, BMD, or fracture pattern) would provide further insight for DRF management. Second, we could not suggest solutions for rare conditions requiring plate removal beyond those described in this article. After plate removal, the cortical defect will be a very vulnerable point for another fracture. Finally, the benefits of inevitable elimination for comminuted fragments rather than fixation or preservation were not compared statistically with control group. Satisfactory radiologic and clinical outcomes with shorter surgery time and easier manipulation should be verified by comparative study in future.

Conclusions

For the maintenance of radiological parameters of the radius, long VLPs are useful for treating elderly patients with DRFs who exhibit metaphyseal comminution, despite concurrent ulnar fractures. The inevitable elimination of irreducible free cortical comminuted fragments does not affect final radiological and clinical outcomes, despite the presence of bony defects in simple radiographs.

Article Information

Author contributions

All the work was done by Soo Min Cha.

Conflict of interest

None.

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Data availability

Contact the corresponding author for data availability.

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Interpositional tricortical iliac bone graft in nonunion of midshaft clavicular fractures

Eun-Seok Son, MD, PhD, Bum-Soon Park, MD, Chang-Jin Yon, MD, PhD, Chul-Hyun Cho, MD, PhD

Department of Orthopedic Surgery, Keimyung University School of Medicine, Daegu, Korea

Background: The purpose of this study was to investigate the radiological and clinical outcomes after interpositional tricortical iliac bone graft with plate fixation for the nonunion of clavicle midshaft fractures.
Methods: Between 2007 and 2020, 17 cases who were treated by interpositional tricortical iliac bone graft with plate fixation for the clavicle midshaft nonunion combined with bone defect were investigated. The mean age was 53 years (range, 22–70 years). The mean follow-up period was 102.2 months (range, 18–193 months). Serial plain radiographs were used to evaluate radiological outcomes. The University of California, Los Angeles (UCLA) score, American Shoulder and Elbow Surgeons (ASES) score, and Quick-disabilities of the arm, shoulder, and hand (DASH) score were used to evaluate clinical outcomes. Complications were also evaluated.
Results: All cases achieved complete bony union with mean healing time of 17.6 weeks (range, 14–22 weeks). The mean clavicle length difference was significantly decreased from 9.1 mm preoperatively to 2.6 mm postoperatively (P<0.001). The mean UCLA and ASES scores were significantly improved from 18.1 and 52.2 before surgery to 30.6 and 88.6 after surgery (both P<0.001), respectively. The mean final Quick-DASH score was 18.0. Three cases (17.6%) developed postoperative complications including two cases of shoulder stiffness and one case of screw irritation.
Conclusions: Interpositional tricortical iliac bone graft with plate fixation for the clavicle midshaft nonunion demonstrated excellent radiological and clinical outcomes. In cases of atrophic nonunion combined with bone defect, this technique is an effective option that can provide structural support and restore clavicle length.
Level of evidence: Level IV, case series.

Keywords: Clavicle; Bone fractures; Midshaft; Nonunion; Bone transplantation

Original Article

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Correspondence to:
Chul Hyun Cho, MD, PhD
Department of Orthopedic Surgery, Keimyung University School of Medicine, 1035 Dalgubeol-daero, Dalseo-gu, Daegu 42601, Korea
Tel: +82-53-258-4772
Email: oscho5362@dsmc.or.kr

Introduction

Clavicle midshaft fractures are common injuries which account for 2%–10% of adult fractures and more than 70% of all clavicle fractures [1-3]. Although conservative or surgical treatments for these fractures produce satisfactory radiological and clinical outcomes, nonunion after the treatment has been reported to be between 0.1%–15% [1,4,5]. A systematic review described that overall incidence of clavicle nonunion is approximately 5.9% [5,6]. However, the incidence may be as high as 15% for some fracture subtypes [5,6].

Due to pain and functional disability, symptomatic clavicle midshaft nonunion may require surgical intervention. Recent studies have reported that clavicle shortening may lead to disturbances in scapular and glenohumeral kinematics as well as cosmetic deformity [1,6-8].

The primary goal of surgical intervention for clavicle midshaft nonunion is to make an alignment and environment conducive to bony union with restoration of clavicle length [6]. Various operative techniques for the treatment of the clavicle midshaft nonunion have been reported, including plate fixation, intramedullary fixation, external fixation, lag screw fixation, bone grafting, or combinations thereof [1,9]. Although there is no prospective comparative study for these treatment options due to the rarity, most surgeons have agreed that open reduction and plate fixation with bone graft is the gold standard technique for the treatment of clavicle midshaft nonunion [10]. Various reconstructive and grafting techniques have been described, but there is some controversy regarding the necessity, type, and technique of bone graft for the treatment of the clavicle midshaft nonunion [1].

In cases of persistent atrophic nonunion, autogenous bone graft is considered the best option due to its osteogenic, osteoconductive, and osteoinductive properties [10]. Several grafting techniques have been introduced, such as cancellous bone graft, strut bone graft, intercalary bone graft, and vascularized bone graft [1,6,8-12]. Zhang et al. [9] reported high rate of bone union after plate fixation and autogenous cancellous bone graft with satisfactory clinical outcomes for atrophic clavicle nonunions. In cases with atrophic fracture ends or bone defect, cortical bone graft may be necessary for restoration of clavicle length [8]. Several studies have advocated that restoration of clavicle length compared with the contralateral side is important for clinical outcomes after surgery [6-8]. Therefore, structural bone graft using autogenous iliac bone is effective solution for atrophic clavicle nonunion combined with bone defect [7,8,10-14]. However, there has been little study on descriptive surgical details for interpositional bone graft with plate fixation and its efficacy for restoration of clavicle length.

The purpose of this study was to evaluate the radiological and clinical outcomes after interpositional tricortical iliac bone graft with plate fixation for the nonunion of clavicle midshaft fractures. This study was conducted to identify whether this technique would promote effective bone healing and restore clavicle length.

Methods

Ethics Statement

The study was approved by the Institutional Review Board of Keimyung University Dongsan Hospital (IRB No. 202405046) and performed in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained.

Patient Selection

We retrospectively reviewed 18 cases who were treated by interpositional tricortical iliac bone graft with plate fixation for clavicle midshaft nonunion combined with bone defect in Keimyung University Dongsan Hospital between 2007 and 2020. The inclusion criteria were patients with (1) symptomatic atrophic nonunion caused by failure of union after conservative or operative treatments; (2) bone defect >10 mm after resection of both sclerotic margins. The exclusion criteria were patients with (1) hypertrophic or oligotrophic nonunion; (2) pathologic nonunion; or (3) follow-up period ≤12 months after index surgery. One patient was excluded due to lack of follow-up evaluation. The remaining 17 patients were included in this study.

Patient's demographic data was listed in (Table 1). The mean age of the patients at the time of index surgery was 53 years (range, 22–70 years). There were 14 males and three females. Nine patients underwent index surgery on left side. The injury mechanism at the time of initial fracture were traffic accidents in nine cases and slip down in eight cases, and the mean interval from initial treatment after fracture to index surgery was 14.3 months (range, 5–60 months).

For the initial fracture, there were five cases of conservative treatment. Twelve cases were transferred to our clinic after surgical treatment at another hospital. All cases demonstrated atrophic nonunion. The causes of nonunion were categorized as follows: five cases of failed conservative treatment, nine cases of fixation failure, and three cases of fracture-related infection. All surgical procedures were performed by a single surgeon (CHC) at a single institution. The mean follow-up period after index surgery was 102.2 months (range, 18–193 months).

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Table 1. Demographic and clinical data of 17 patients

Case no.	Sex	Age (yr)	Involved side	Initial treatment	Interval from IT to IS (mo)	Union time (mo)	UCLA score		ASES score		Final Quick-DASH score	FU period (mo)	CLD		Complication
							Preoperative	Final	Preoperative	Final			Preoperative	Postoperative	
1	Male	64	Left	Conservative	7	17	15	35	57	100	0	193	6.9	4.9	-
2	Male	70	Left	Conservative	12	16	21	35	64	100	0	190	14.9	4.1	-
3	Male	56	Right	ORIF	20	16	14	26	43	81	46	41	15.2	5.6	Stiffness
4	Male	44	Left	Conservative	10	18	17	22	58	65	65	49	16.4	5.3	-
5	Male	66	Left	ORIF	16	22	20	33	54	96	27	31	15.7	0.7	-
6	Male	60	Left	ORIF	5	17	13	27	32	87	38	18	8.2	1.1	-
7	Female	53	Right	Conservative	60	20	17	26	59	81	43	167	10.2	2.2	Stiffness
8	Male	65	Right	Conservative	7	14	19	33	51	90	5	162	9.8	1.6	-
9	Male	52	Right	ORIF	7	20	18	30	59	87	30	149	7.5	1.9	-
10	Male	42	Left	ORIF	9	20	20	33	54	95	2	136	2.5	1.3	-
11	Male	39	Right	ORIF	6	18	13	33	15	95	2	120	12.8	0.3	Screw irritation
12	Male	60	Right	ORIF	9	16	20	33	43	90	5	120	9.3	3.0	-
13	Male	69	Right	ORIF	13	16	15	33	48	95	2	90	3.5	2.8	-
14	Male	48	Right	ORIF	32	18	33	35	93	100	0	82	2.5	1.9	-
15	Female	40	Left	ORIF	15	14	22	33	70	100	2	80	3.8	1.9	-
16	Female	22	Left	ORIF	5	16	10	27	28	80	5	71	11.0	1.4	-
17	Male	48	Left	ORIF	11	22	21	26	60	65	30	39	5.0	3.7	-

IT, initial trauma; IS, index surgery; UCLA, University of California, Los Angeles; ASES, American Shoulder and Elbow Surgeons; DASH, disabilities of the arm, shoulder, and hand; FU, follow-up; CLD, clavicle length difference; ORIF, open reduction and internal fixation.

Operative Technique

With the patient in the supine position, a skin incision was made along the longitudinal axis of the center of the fracture site or according to the previous surgical scar. The nonunion site was sufficiently exposed, and the surrounding fibrous tissues were removed. Sclerotic bone was then completely resected until a healthy bone is produced with bleeding. Length of the defect area was measured using a ruler after trimming both margins perpendicular to the longitudinal axis of the clavicle. Depending on the measured length of the bone defect, a tricortical iliac bone block was taken using an oscillating saw. Cancellous bone was also harvested. To obtain structural support, the tricortical iliac bone block was interposed between both fragments, followed by plate fixation. The plate with sufficient length was selected and at least three screws were inserted on each side of the proximal and distal fragments to provide sufficient fixation.

Dynamic compression screw technique was used to increase contact surface between the host bone and the graft bone on each side (Fig. 1). If the interposed iliac bone block is long, it was fixed with a screw through the hole of the plate. In six cases, a 3.5-mm reconstruction locking compression plate (Synthes) was used and an anatomical pre-contoured clavicle plate (Acumed) was used in the other 11 cases. Wearing the arm sling for 4 weeks after index surgery, active and passive shoulder motions were begun once the pain was tolerable.

Outcome Measurement

Radiological outcomes were assessed by serial plain radiographs to confirm bone union and clavicle length differ-

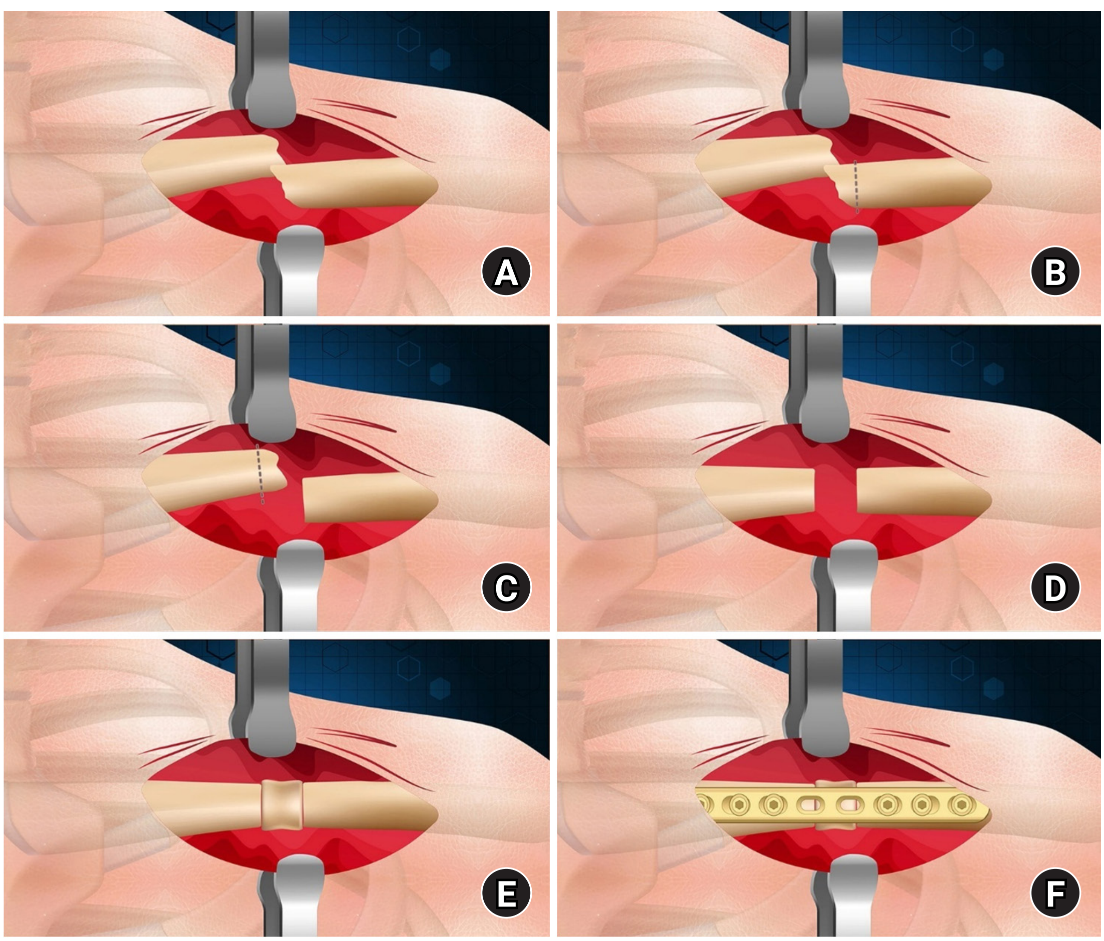

Fig. 1. Steps of the interpositional tricortical iliac bone graft with plate fixation. (A) Exposure of the nonunion site. (B, C) Resection of sclerotic bone with trimming both margins to be perpendicular to the long axis of the clavicle. (D) Measurement of the length of the bone defect. (E) Interposition of tricortical iliac bone block between both fragments. (F) Plate and screws fixation.

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ence (CLD) after index surgery. Bony union was defined as a completely bridging bone in both anterosuperior and oblique views of clavicle. Using both anteroposterior clavicle plain radiograph, total length of the clavicle was measured bilaterally and defined as the linear distance between the midpoint of the acromial end and the midpoint of the sternal end of the clavicle (Fig. 2). Clinical outcomes were assessed using the University of California, Los Angeles (UCLA) score, American Shoulder and Elbow Surgeons (ASES) score, and Quick-disabilities of the arm, shoulder, and hand (DASH) score. Intraoperative and postoperative complications were also evaluated.

Statistical Analysis

Statistical analysis was performed using IBM SPSS ver. 25.0 (IBM Corp.). The Wilcoxon signed-rank test was used for comparison of ASES and UCLA scores between preoperative and final follow-up evaluations. The point biserial correlation analysis, Kendall rank correlation analysis, and Spearman correlation test were used to determine the correlation between clinical outcomes and variables such as age, sex, involved side, cause of nonunion, initial treatment, interval from initial treatment to index surgery, union time, and final CLD. Statistical significance was set at P-values of <0.05.

Results

In all cases, complete bony union was achieved (Figs. 3 and

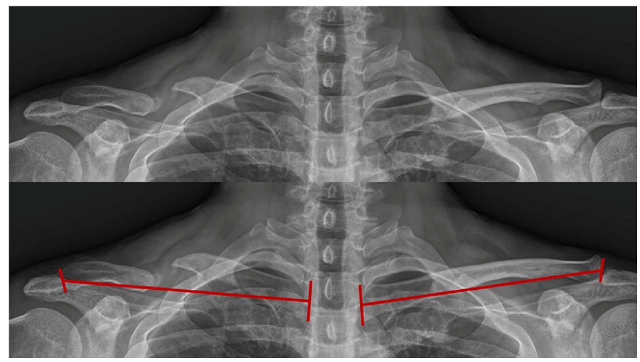

Fig. 2. Preoperative radiographs of 48-year-old man (case no. 14) with right atrophic clavicle nonunion. The clavicle length (red line) was determined on standard anteroposterior plain radiograph by measuring the linear distance between the midpoint of the acromial end and the midpoint of the sternal end of the clavicle.

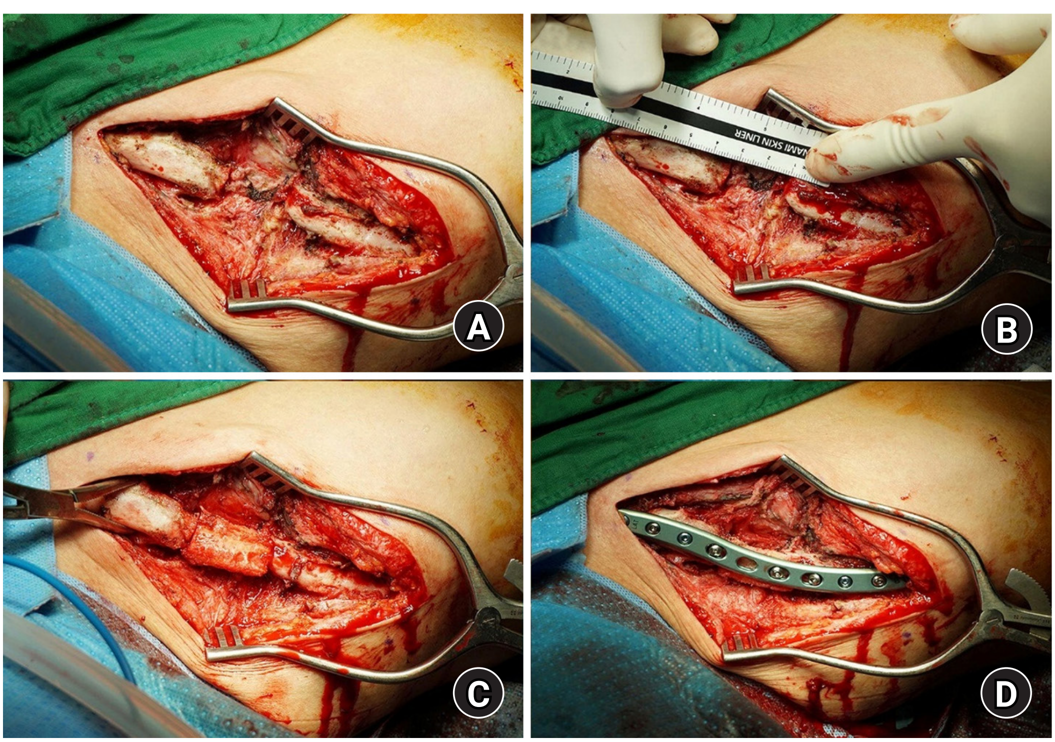

Fig. 3. Intraoperative photos (case no. 14). (A) Sufficient resection of sclerotic bone. (B) Measurement of the length of the bone defect. (C) Interposition of tricortical iliac bone block. (D) Plate and screws fixation.

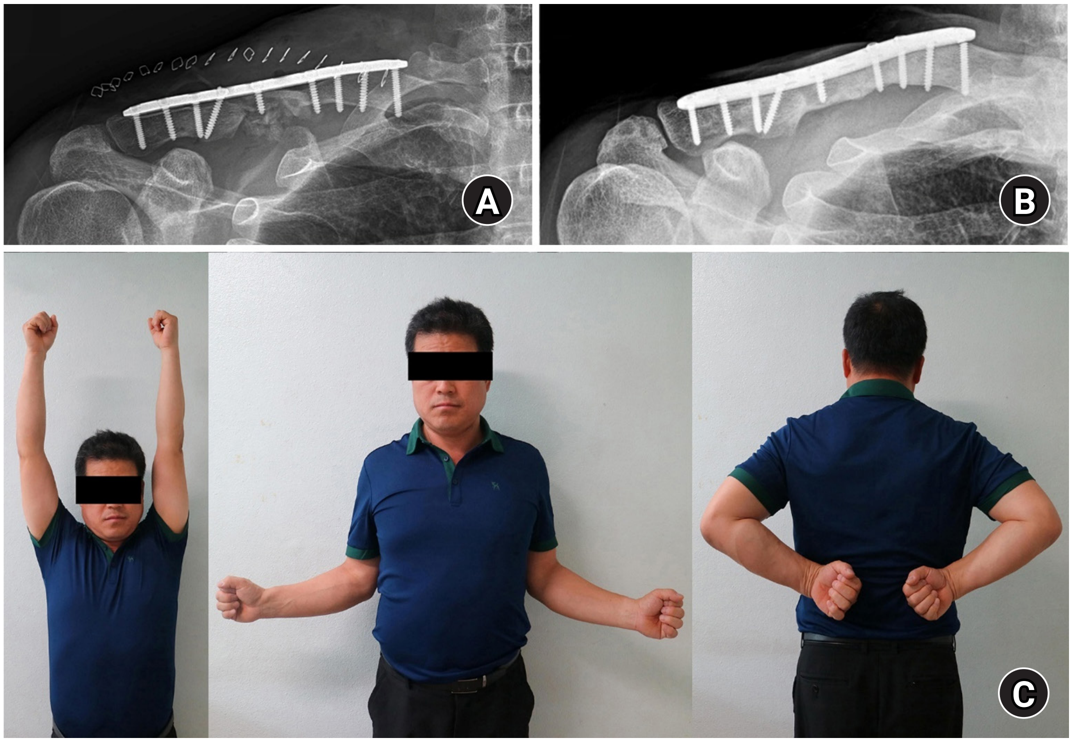

Fig. 4. Postoperative radiographs and clinical photos (case no. 14). (A) Immediate postoperative image. (B) Image at final follow-up evaluation. (C) Clinical photos at final follow-up evaluation. Written informed consent for using the images was obtained from the patient.

Table 2. Correlations between final clinical scores and variables

Variable	Final UCLA score		Final ASES score		Final Quick-DASH score	
	r	P-value	r	P-value	r	P-value
Age	0.357	0.159	0.321	0.208	–0.014	0.957
Sex	–0.227	0.382	–0.070	0.789	–0.025	0.923
Involved side	0.219	0.399	0.139	0.595	–0.182	0.484
Type of nonunion	–0.157	0.544	–0.132	0.606	0.327	0.197
Initial treatment	0.064	0.808	0.086	0.743	–0.155	0.552
From IT to IS	0.009	0.973	0.188	0.470	0.047	0.859
Union time	–0.249	0.334	–0.218	0.401	0.272	0.291
CLD	–0.217	0.402	–0.166	0.525	0.099	0.705

UCLA, University of California, Los Angeles; ASES, American Shoulder and Elbow Surgeons; DASH, disabilities of the arm, shoulder, and hand; IT, initial trauma; IS, index surgery; CLD, clavicle length difference.

4). The mean time of union was 17.6 weeks (range, 14–22 weeks). The mean CLD was significantly decreased from 9.1 mm (range, 2.5–16.4 mm) before surgery to 2.6 mm (range, 0.3–5.6 mm) after surgery (P<0.001).

The mean UCLA and ASES scores were significantly improved from 18.1 and 52.2 before surgery to 30.6 and 88.6 after surgery (both P<0.001). The mean final Quick-DASH score was 18. No differences were observed between final clinical scores and variables including age, sex, involved side, cause of nonunion, initial treatment, interval from initial trauma to index surgery, union time, and final CLD (P>0.05) (Table 2).

Three cases (17.6%) developed postoperative complications, including two cases of shoulder stiffness and one case of screw irritation. No donor site morbidity was found for any case. A patient (case no. 7) with shoulder stiffness underwent implant removal and arthroscopic capsular release at 12 months after the index surgery. A patient (case

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no. 11) with screw irritation underwent implant removal at 18 months after the index surgery. Two patients (cases no. 8 and 10) without any discomfort underwent implant removal by patient's request. There were no complications such as refracture after implant removal.

Discussion

Plate fixation with bone graft is considered the best choice for atrophic clavicle nonunion [6,15]. Undoubtedly, when compared with other fixation techniques, plate fixation has more advantages in controlling rotational force and recovering from clavicle shortening. However, techniques for plating or bone graft are still controversial.

Most surgeons agree that bone graft is necessary for the treatment of clavicle nonunion. Nevertheless, several studies have reported good radiological and clinical outcomes with plate fixation or external fixation without bone graft [16,17]. Huang et al. [17] reported the utilization of a dynamic compression plate without bone graft is an effective option in cases with atrophic clavicle nonunion. In contrast, van der Meijden et al. [3] recommended that plate fixation and bone graft is the best treatment option for symptomatic clavicle midshaft nonunion, including local bone graft for hypertrophic nonunion and iliac bone graft for atrophic nonunion.

Although there is controversy for the shortening of the clavicle length after fracture, it has been reported that, if the clavicle is shortened by more than 15–20 mm, it can cause shoulder abduction weakness and substantial problems in shoulder function due to abnormal kinematics [6-8]. Therefore, restoration of the clavicle length in surgical treatment of atrophic clavicle nonunion is important for recovery of shoulder function. Intercalary tricortical iliac bone graft or free vascularized bone graft has been reported as a good treatment options for atrophic nonunion with severe bone defect. Bone defects of 1.5–3 cm should be interposed with a tricortical iliac bone graft to prevent the shortening of the clavicle length [6,14]. A vascularized bone graft can be used for extremely rare cases with larger defects >3 cm [6,14].

A few surgeons have advocated the necessity of intercalary autogenous bone graft for atrophic clavicle nonunion [7,8,11,13,14,18]. Simpson and Jupiter [18] reported excellent radiological and clinical outcomes after plate fixation with intercalary tricortical iliac bone graft for clavicle midshaft nonunion, especially in the case of atrophic nonunion or bone defect. Ballmer et al. [11] reported satisfactory results after intercalary tricortical iliac bone graft in patients with bone defects over 15 mm. They emphasized that intercalary tricortical iliac bone graft is important for restoration of the function of the acromioclavicular joint and sternoclavicular joint with the preservation of the costoclavicular space [11]. Rollo et al. [8] reported intercalary allograft bone graft can be used in place of vascularized bone graft for cases with significant bone loss. Lim et al. [12] introduced the dual bone graft technique with plate fixation, which showed satisfactory results. Bridging over the nonunion gap, iliac cortical bone graft was placed under the nonunion site and cancellous bone was packed into the gap [12]. We totally agreed on the necessity of structural bone graft for atrophic clavicle nonunion and have used interpositional tricortical iliac bone graft technique for the cases with bone defect >10 mm after resection of both sclerotic margins. The present study demonstrated that this technique for atrophic clavicle nonunion produced excellent the radiological and clinical outcomes. To prevent shortening of the clavicle length and provide structural support, a tricortical iliac bone with 2–3 mm long to match the length of the bone defect area was harvested. Accordingly, a tricortical iliac bone block was interposed in a somewhat tight manner. Then, plate and screws were fixed using a dynamic compression technique. These meticulous procedures may have a positive effect on complete bone healing and prevention of refracture after implant removal. The results of this study have led us to believe that several factors attributed to the excellent radiological and clinical outcomes. First, the interpositional tricortical bone graft restored the clavicle length. Second, a dynamic compression plating technique with autogenous bone graft provided both biological healing ability and mechanical stability.

Surgeries for clavicle midshaft nonunion are related to more complications when compared with those for acute fractures [13,19,20]. Faraud et al. [19] reported that 15 out of 21 cases (71.4%) achieved complete bone healing after plate fixation and bone graft for the clavicle midshaft nonunion. Six cases with complications required a revision procedure, including three cases of infection and three cases of fixation failure. Wiss and Garlich [20] reported

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that 63 out of 71 cases (87.3%) achieved complete bone union after plate fixation with or without bone graft for the clavicle midshaft nonunion. Three cases (4.2%) with revision surgery achieved bone union, but six cases (8.5%) had remained nonunion. Clavicle nonunions caused by failed previous surgery can decrease the biologic healing potential and may lead to failure of union after the revision surgery [12]. In the present study, 12 cases presented with atrophic nonunion after surgery including, nine cases of fixation failure and three cases of fracture-related infection. However, all cases achieved complete bone union without any major complications.

Superior plating is associated with hardware prominence due to the subcutaneous position of the plate and sometimes needed hardware removal [1]. Hollo et al. [7] reported that plate fixation with cortical bone graft for clavicle nonunion produced a high rate of bone union with restoration of the clavicle length. However, four refractures occurred after plate removal and three of them required revision [7]. Disadvantages of autogenous iliac bone graft included the limited volume of available bone, increased operative time, and donor site morbidity such as pain, hematoma formation, and iliac fracture [6,15,20]. Beirer et al. [13] reported excellent clinical and radiologic results after iliac bone graft and plate fixation for 14 cases with clavicle nonunion or malunion. However, two cases experienced a secondary fracture of the anterior superior iliac spine as a complication at the donor site and one case experienced refracture after implant removal [13]. They emphasized that the decision and timing of implant removal should be individually and carefully counseled. The present study revealed that three cases (17.6%) had postoperative complications, including two cases of shoulder stiffness and one case of screw irritation. No donor site morbidity was found for any case. Although only four cases had implant removal, the patients did not have refracture after implant removal.

This study has several limitations. First, this is a retrospective study. Second, the number of cases was small. Third, there was no comparison with the control group. Fourth, clavicle length measured by plain radiograph may not be accurate due to distorted rotation caused by X-ray beams.

Conclusions

Interpositional tricortical iliac bone graft with plate fixation for the clavicle midshaft nonunion demonstrated excellent radiological and clinical outcomes. In cases of atrophic nonunion combined with bone defect, this technique is an effective option that can provide structural support and restore clavicle length.

Article Information

Author contributions

Conceptualization: ESS. Data curation, Formal analysis: BSP, CJY. Writing-original draft: ESS, BSP. Writing-review & editing: CJY, CHC. All authors read and approved the final manuscript.

Conflict of interest

Chul-Hyun Cho is an editorial board member of the journal but was not involved in the peer reviewer selection, evaluation, or decision process of this article. No other potential conflicts of interest relevant to this article were reported.

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Data availability

Contact the corresponding author for data availability.

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Outcomes of open reduction and internal fixation using 2.0/2.4 mm locking compression plate in isolated greater tuberosity fractures of humerus

Sung Choi, MD[1], Dongju Shin, MD[2], Sangwoo Kim, MD[1], Byung Hoon Kwack, MD[1]

[1]Department of Orthopedic Surgery, Daegu Fatima Hospital, Daegu, Korea
[2]Department of Orthopedic Surgery, W General Hospital, Daegu, Korea

Background: The purpose of this study was to retrospectively evaluate the radiographic and clinical results of a small single or double low-profile plate fixation of 2.0/2.4 mm locking compression plate (LCP) in treating isolated greater tuberosity (GT) fractures of the humerus.

Methods: From June 2015 to October 2022, patients who underwent LCP in treating isolated GT fractures of the humerus were included in this study. The radiological and clinical results were analyzed in 15 patients who underwent open reduction and internal fixation used 2.0/2.4 mm LCP.

Results: Bone union was achieved in 14 patients (93.3%) and one failed case was treated with a 2.4 mm single LCP fixation. Radiological union was achieved within 10–20 weeks. Complications occurred in two patients (13.3%), including the reduction failure and shoulder stiffness. At the final follow-up, the average clinical scores were as follows: a visual analog scale for pain of 2.1 (range, 0–5) and a University of California, Los Angeles score of 27.2 (range, 18–31). Regarding range of motion (ROM), the average active ROMs were 142° for forward flexion (range, 120°–150°), 147.1° for abduction (range, 120°–180°), and 59.3° for external rotation (range, 45°–80°). For internal rotation, the average was observed to reach the 10th thoracic vertebra (range, 1st lumbar vertebra–7th thoracic vertebra).

Conclusions: The clinical and radiologic outcomes of treating isolated GT fracture using 2.0/2.4 mm LCP were favorable, and double low-profile plate fixation may be beneficial for sufficient fracture stability if possible.

Level of evidence: Level IV, case series.

Keywords: Shoulder; Shoulder fractures; Internal fracture fixation; Internal fixators; Bone plates

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Correspondence to:
Byung Hoon Kwack, MD
Department of Orthopedic Surgery, Daegu Fatima Hospital, 99 Ayang-ro, Dong-gu, Daegu 41199, Korea
Tel: +82-53-940-7324
Email: kwackbyunghoon@nate.com

Introduction

Of proximal humeral fractures, isolated greater tuberosity (GT) fractures of humerus accounted for approximately 20% [1]. For patients with proximal humeral fractures, 3.5 mm locking compression plate (LCP) Proximal Humeral Internal Locking System (PHILOS, DePuy Synthes) was commonly used for fixation. Geiger et al. [2] reported that the PHILOS plate provided sufficient fracture stabilization for the treatment of proximal humeral fractures in elderly patients and that subacromial impingement occurred in approximately 20% of proximal humeral fractures treated with the PHILOS plate, which was mainly due to the superior position of the plate. For humerus avulsion type GT fracture with small fragments, the recommended placement of a locking plate relatively superiorly might provide more secure fixation of the fragments, but might increase impingement [3]. To prevent secondary subacromial impingement and secure fixation in the treatment of isolated GT fractures of the humerus, several authors have proposed various techniques, including cannulated screw fixation, tension band wiring, and arthroscopic double-row suture anchor fixation [3–5]. However, complications such as cortical breakage and reduction loss, anchor pull-out failure, and rotator cuff damage have been reported in elderly patient with osteoporosis or osteopenia [5–7].

In a comparative biomechanical study using animals, Gaudelli et al. [8] compared fixation of humerus split type GT fractures with a calcaneal locking plate (DePuy Synthes), a tension band, and a double row suture bridge and reported that a locking plate fixation provided the strongest and stiffest biomechanical fixation. Several authors have showed reliable stability and good clinical results in the fixation of isolated GT fractures using low-profile system, such as the one-third tubular plate, LCP mesh plate, LCP hook plate, or X-shaped midfoot locking plate [9–14]. Authors thought that 2.0/2.4 mm LCP miniplate (DePuy Synthes) might enable specific fragment fixation and enhance the low-profile advantage in isolated GT fractures. To the best of our knowledge, no studies have been reported fixation of 2.0/2.4 mm LCP in isolated GT fractures of humerus. The purpose of this study was the results of treating isolated GT fractures with open reduction and internal fixation (ORIF) using a 2.0/2.4 mm LCP.

Methods

Ethics Statement

The study was approved by the Institutional Review Board of Daegu Fatima Hospital (IRB No. 2024-10-001) and performed in accordance with the principles of the Declaration of Helsinki. Written informed consent was waived.

Patient Selection

We retrospectively studied the records of patients with isolated GT fractures who underwent ORIF between June 2015 and October 2022 and could be followed up for more than 6 months. Among the 66 patients, we select the 15 patients who underwent ORIF used 2.0/2.4 mm LCP and evaluate the clinical and radiological outcomes. The surgical indication was an at least 5 mm displacement of the GT as observed in either simple radiography or three-dimensional computed tomography (CT) (Fig. 1). All fractures were evaluated with the anteroposterior, Grashey and scapular Y view throughout the follow up period. All patients underwent CT scans to assess the pattern of fracture, degree of comminution and the morphological classification of the GT fragment (avulsion, split, or depression) according to Mutch et al. [14]. All patients underwent magnetic resonance imaging scans to assess the rotator cuff and associated injuries.

Exclusion criteria encompassed (1) individuals without a minimum 6-month follow-up postsurgery; (2) those with a prior history of shoulder surgery; (3) participants with additional injuries necessitating separate surgical interventions; (4) individuals experiencing neurovascular injuries preoperatively; and (5) patients with nonunion of the GT fracture.

Surgical Technique

Under the general anesthesia, the patient was placed in beach chair position on the operation table. The fracture site was visualized using a deltopectoral approach, and the supraspinatus tendon attached to the displaced GT

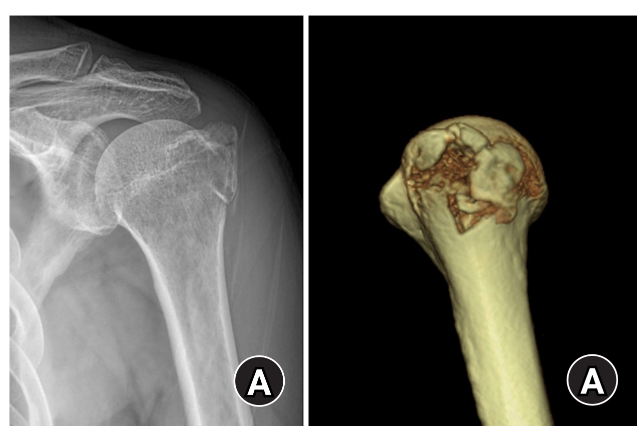

Fig. 1. A shoulder anteroposterior (A) three-dimensional computed tomography (B) of the right shoulder of a 58-year-old male patient with a displaced and comminuted isolated fracture of the greater tuberosity of the humerus.

fragment was stabilized with Ethibond (Ethicon) sutures. We then pulled it downwards to achieve reduction of the fracture site, and confirmation of reduction was done using a C-arm. Subsequently, a 2.0/2.4 mm LCP miniplate was positioned on the fracture site and aligned with the contours of the fracture using bender. Temporary fixation was attempted using K-wires. In cases of severe comminution, additional anchors (Y-knot anchor or raptomite suture anchor) were used on the proximal fracture site before plating and passed the suture through the rotator cuff to reduce the GT fracture. Then double plates were applied to each fracture segment after aligning the contours. After confirming reduction of the fracture segments and plate position, screw fixation was performed (Fig. 2). To provide appropriate tension to the rotator cuff, augmentation was performed using Ethibond or Fiberwire (Arthrex) through the empty holes of the 2.0/2.4 mm LCP. In some cases, tension band wires were used to increase the fixation strength and stability of the rotator cuff. In cases of poor bone quality, autograft or allograft bone grafting was performed in conjunction. Postoperative radiography was preformed to assess the fracture reduction and fixation.

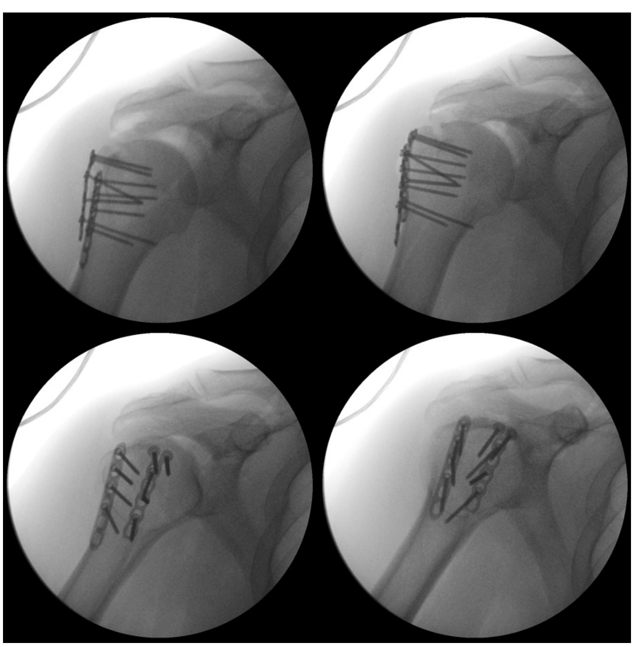

Fig. 2. An immediate postoperative C-arm showing open reduction and internal fixation using dual 2.4 mm locking compression plate for a displaced and comminuted isolated fracture of the greater tuberosity of the humerus.

Rehabilitation

All patients received standardized postoperative care, with the same treatment protocol applied regardless of the fracture type or degree of comminution. After the surgery, a shoulder immobilizing brace with an abduction pillow was used for a duration of 4 weeks. During the second week post-surgery, patients began gentle passive forward flexion arm exercises. At the 4-week mark, the brace and abduction pillow were removed, and patients initiated passive range of motion (ROM) exercises in all directions, as well as active mobilization.

Radiologic and Clinical Evaluation

We evaluated dual-energy X-ray absorptiometry to measure the lumbar spine and femoral bone mineral density. As a criterion for diagnosing osteoporosis, a T score of –1 to –2.5 was defined as osteopenia and below –2.5 was defined as osteoporosis. During the follow-up period, we evaluated the following radiological parameters: bone union and time to union. Time-to-union was determined as the point when cortical continuity was observed on one of the three planes of plain radiography (anteroposterior, Grashey, or scapular Y view), and when tenderness at the fracture site subsided. Anatomical reduction was defined as a distance between the GT and the humeral head of 4 to 10 mm at the final follow-up. Similarly, a loss of reduction was defined as a displacement greater than 3 mm at the final follow-up compared to the immediate postoperative radiograph. For all surgically treated patients, follow-up imaging was conducted at least up to 6 months postoperatively, with evaluations scheduled at 1-, 2-, 3-, and 6-month intervals. Clinical outcomes were assessed based on the degree of pain and the restoration of daily functional activities. At the final follow-up, the following clinical outcome parameters were evaluated: visual analog scale (VAS) score, ROM of the shoulder joint, and the Shoulder Rating Scale of the University of California, Los Angeles (UCLA) score. Postoperative complications were also carefully assessed.

Results

A total of 15 patients with isolated GT fractures underwent ORIF using 2.0/2.4 mm LCP. The average age of the patients was 63.8 years (range, 50–78 years), and the average follow-up period was 15.6 months (range, 6–78

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Table 1. Summary of demographic data

Patient no.	Age (yr)	Sex	Affected side	BMD	Injury mechanism	Dislocation	Classification	Combined injury	Time to surgery (day)	Union time (wk)	No. of plate		Augmentation		Bone graft	Complication
													Tension suture	Suture anchor		
1	73	Male	Lt	Osteopenia	Hit by mass	O	Avulsion	-	16	10	Dual	2.4+2.0	1	-	-	-
2	72	Female	Rt	Osteoporosis	Simple fall	O	Depression	-	21	10	Dual	2.4+2.4	3	-	Autograft	-
3	58	Male	Lt	-	Idiopathic	-	Avulsion	-	25	16	Dual	2.4+2.4	1	-	Autograft	-
4	63	Female	Rt	Osteopenia	Simple fall	O	Avulsion	-	6	12	Dual	2.4+2.4	1	-	-	-
5	65	Female	Lt	Osteopenia	MVA	O	Split	Rt 1st MC neck fx Multiple rib fx	6	12	Dual	2.4+2.4	3	-	-	-
6	70	Male	Rt	Osteopenia	Fall from height	O	Avulsion	-	11	12	Dual	2.0+2.0	2	-	-	-
7	52	Female	Rt	Osteopenia	Simple fall	-	Split	-	13	17	Single	2.4	1	-	Allograft	-
8	73	Female	Lt	Osteopenia	Simple fall	-	Avulsion	-	7	20	Single	2.4	-	-	Allograft	-
9	50	Female	Lt	-	Hit by mass		Avulsion	-	9	20	Single	2.4	1	-	-	-
10	68	Female	Rt	-	Simple fall	O	Split	-	18	16	Single	2.4	3	1	Autograft	-
11	59	Male	Rt	-	Hit by mass	O	Split	Rt 4th finger distal phalanx fx	12	20	Single	2.4	-	1	-	Stiffness
12	66	Female	Rt	Osteoporosis	MVA	-	Split	-	40	20	Single	2.0	-	1	Autograft	-
13	60	Male	Lt	-	MVA	-	Spllt	Rt tibiofibular open fx	11		Single	2.4	-	1	-	Reduction failure
14	50	Female	Rt	-	MVA	-	Avulsion	Lt Proximal humerus fx Rt tibia plateau fx	4	16	Single	2.0	-	1	-	-
15	78	Female	Lt	Osteoporosis	Simple fall	-	Split	-	11	16	Single	2.0	-	1	-	-

BMD, bone mineral density; Lt, left; Rt, right; MVA, motor vehicle accident; MC, metacarpal; Fx, fracture.

months). Among the patients, five were male and 10 were female. Eight cases involved the right side, while seven cases involved the left side. The fractures occurred due to various mechanisms, including simple falls, motor vehicle accidents, being hit by a heavy object, falls from height, and idiopathic causes. Seven patients had accompanying anterior dislocation of the shoulder, and four patients had a combined fracture at a different site. Prior to the surgery, all patients were assessed and found to have intact rotator cuffs without any evidence of tears. The surgical treatment was performed, on average, 14 days after the trauma (range, 4–40 days). Important demographic data of the study group are shown in Table 1.

Radiological union was achieved within 10–20 weeks in all patients except one case of reduction failure. Although there was a reduction failure, bone union was confirmed through a subsequent reoperation using a 3.5 mm LCP hook plate (DePuy Synthes) (Fig. 3). In all other patient groups, no displacement greater than 3 mm was observed, and anatomical reduction was achieved. At the final follow-up, the average clinical scores were as follows: a VAS for pain of 2.1 (range, 0–5) and a UCLA score of 27.2 (range, 18–31). Regarding ROM, the average active ROMs were 142° for forward flexion (range, 120°–150°), 147.1° for abduction (range, 120°–180°), and 59.3° for external rotation (range, 45°–80°). For internal rotation, the average was observed to reach the 10th thoracic vertebra (range, 1st lumbar vertebra–7th thoracic vertebra) (Table 2).

No postoperative infections or neurovascular complications were observed in any of the patients. However, one patient experienced shoulder stiffness. At the sixth week after the operation, the affected shoulder showed limited passive ROM: 80° of forward flexion, 90° of abduction, and 10° of external rotation, indicating restricted mobility com-

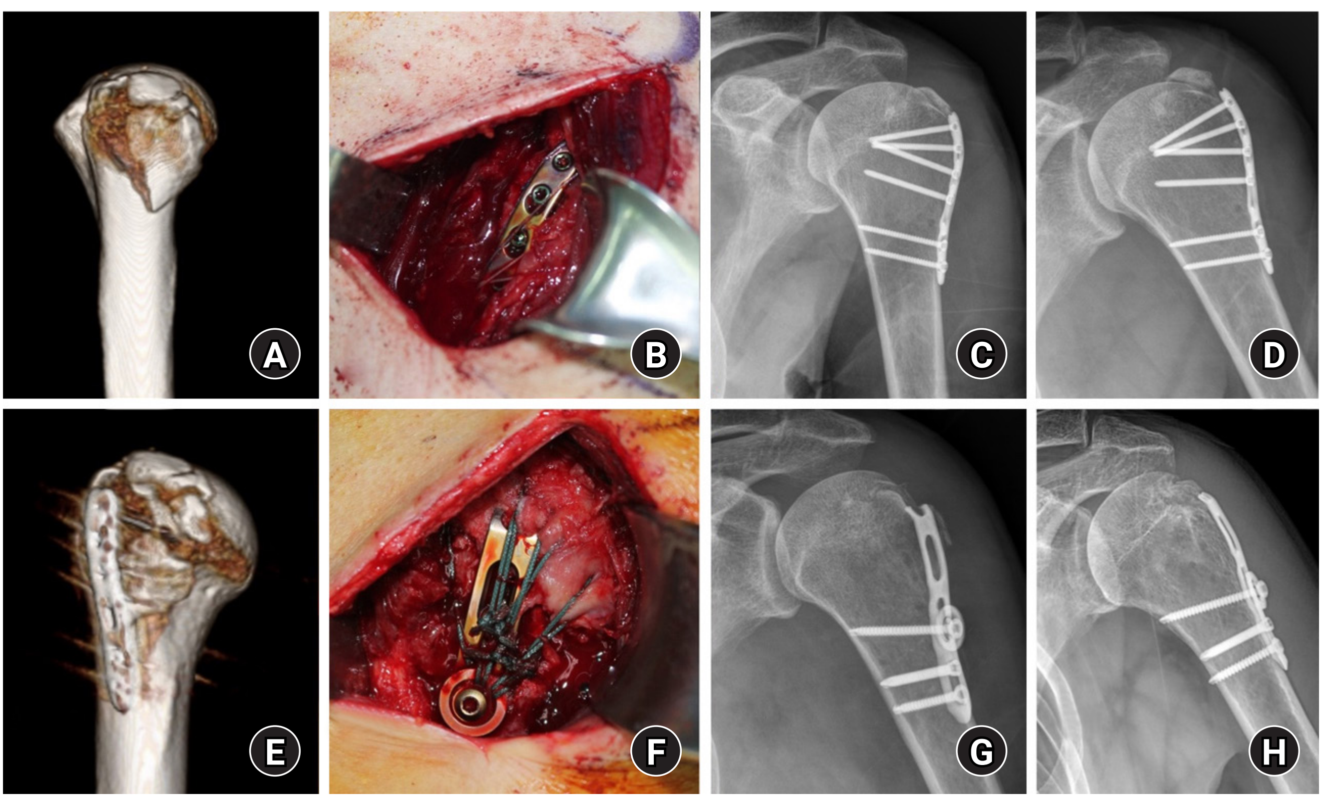

Fig. 3. (A) Three-dimensional computed tomography (CT) of a 60-year-old male patient showed a split ftype comminuted isolated fracture of the greater tuberosity of the humerus on left shoulder. (B, C) A single 2.4 mm locking compression plate (LCP) with augmentation anchor suture fixation was performed. (D, E) Postoperative 1 week shoulder anteroposterior (AP) radiograph and three-dimensional CT showed reduction loss. (F, G) A 3.5 mm LCP hook plate with augmentation tension-band suture fixation was performed. (H) Postoperative 6 months AP radiograph showed complete union of the fracture.

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Table 2. Clinical outcomes at the final follow-up

Variable	Mean (range)
VAS pain score	2.1 (0–5)
Range of motion	
Forward flexion (°)	142 (120–150)
Abduction (°)	147.1 (120–180)
External rotation (°)	59.3 (45–80)
Internal rotation (level of spine)	T10 (L1–T7)
Functional score	
UCLA	27.2 (18–31)

VAS, visual analog scale; UCLA, University of California, Los Angeles.

pared to the contralateral arm. To address this issue, we administered an intra-articular injection of steroids and initiated aggressive rehabilitation from the third postoperative month. After the final follow-up, significant improvements in the ROM were observed.

Discussion

This study aimed to evaluate the results of a small single or double 2.0/2.4 mm LCP miniplate fixation. Shin et al. [9] reported that they modified a one-third tubular plate (DePuy Synthes) into a hook plate to fix isolated GT fractures and achieved fracture union in all cases, but performed a reoperation using the same method in one case where the metal failure. Even in small and comminuted fractures of isolated GT fractures, 3.5 mm LCP hook plate provided less subacromial impingement and sufficient stability and led to satisfactory clinical and radiologic results [10,11]. Bogdan et al. [12] showed that the use of a variable angle LCP mesh plate (2.4/2.7 mm) (DePuy Synthes) to fix isolated GT fractures resulted in relatively good clinical results, demonstrating the benefit of a low-profile implant and no complication of impingement. Chen et al. [13] reported satisfactory clinical results using a X-shaped midfoot locking plate (DePuy Synthes) for isolated GT fractures without complication such as subacromial impingement, nonunion, secondary displacement, and implant loosening. In our study, we demonstrated bone union in 14 out of 15 cases (93.3%) using small single or double low-profile LCP fixation for isolated GT fractures, and we believe that this technique can be considered a good alternative technique for small or comminuted isolated GT fractures in which conventional plates cannot be used.

Kim et al. [1] reported that isolated GT fractures were more common in young and healthy male population, with a mean age of 42.8 years (range, 19–73 years), and that concomitant shoulder dislocation occurred in 6.9%. In our study, the mean age was 63.8 years (range, 50–78 years), the incidence was higher in women, 60% had osteoporosis and osteopenia, and 46.7% had concomitant shoulder dislocation. As society ages, the physical characteristics of patients were changing, and it was especially important to secure sufficient stability in isolated GT fractures in elderly patients with osteoporosis or osteopenia.

Lee et al. [11] treated isolated GT fractures using a 3.5 mm LCP hook plate in 21 patients (mean age, 64 years), 15 of whom had osteoporosis and osteopenia, and reported adequate stability and satisfactory clinical and radiographic results. In a comparative biomechanical study of clavicle fracture fixation, Pastor et al. [15] showed that low-profile 2.0/2.5 mm dual plates had significantly higher initial stiffness and similar fracture resistance compared to a single 3.5 mm locking plate. In our study, one case of reduction failure occurred after fixation of a single 2.4 mm LCP in isolated GT fractures, and bone union was achieved through reoperation using a 3.5 mm LCP hook plate. Although we were able to achieve bone union with single low-profile plate fixation, we believe that double low-profile plate fixation would be more effective than single low-profile plate fixation for sufficient fracture stability.

Lee et al. [11] reported that two patients (9.5%) had bursal side partial thickness rotator cuff tears due to hook irritation, and these patients were repaired using a simple transosseous technique. In our study, a small single or double 2.0/2.4 mm LCP miniplate fixation was feasible for isolated GT fractures without accessing the rotator cuff as much as a hook plate.

The present study has certain limitations that should be acknowledged. Firstly, the small number of included patients underscores the necessity for future comparative studies with a larger sample size and extended follow-up periods. Secondly, the absence of a comparative group is a result of introducing a new technique for isolated GT fractures in this study. Currently, the authors are in the process of gathering and evaluating data for comparison, especially with the 3.5 LCP hook plate, in the context of the next research study. Thirdly, the absence of biomechanical studies is also a challenge that needs to be addressed. Fourth, it is important to note that the present study is retrospective. However, the strength of this study is that the surgeries were performed at a single center using the same surgical technique and products from the same company, although the number of fixation plates varied.

In summary, the authors experienced good clinical and radiological outcomes of ORIF using 2.0/2.4 mm LCP for isolated GT fractures. This fixation methods maximize the advantages of a low-profile system compared to using a 3.5 mm LCP. It further reduces the risk of subacromial impingement and provides better fixation for small or comminuted fractures, enabling fragment-specific fixation and facilitating anatomical reduction. If possible, double low-profile plate fixation would be more effective than single low-profile plate fixation for sufficient fracture stability. Moreover, it offers a solution to the previously reported complication of rotator cuff damage caused by the Hook plate. Therefore, it is suggested that the 2.0/2.4 mm LCP serves as an effective approach for addressing and preventing rotator cuff injuries, making it a beneficial fixation method in both radiological and clinical settings.

Conclusions

The 2.0/2.4 mm LCP fixation for isolated GT fractures serves as an effective approach for addressing and preventing rotator cuff injuries, making it a beneficial fixation method in both radiological and clinical settings. If possible, double low-profile plate fixation would be more effective than single low-profile plate fixation for sufficient fracture stability.

Article Information

Author contributions

Conceptualization: SC. Data curation: SC, DS. Formal analysis: BHK. Investigation: SC, DS, SK. Supervision: DS, BHK. Visualization: SK, BHK. Writing-original draft: BHK. Writing-review & editing: SC, DS, SK, BHK. All authors read and approved the final manuscript.

Conflict of interest

Dongju Shin is an editorial board member of the journal but was not involved in the peer reviewer selection, evaluation, or decision process of this article. No other potential conflicts of interest relevant to this article were reported.

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Data availability

Contact the corresponding author for data availability.

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Author correction: "Does the operator's experience affect the occurrence of complications after distal radius fracture volar locking plate fixation? A comparative study of the first four years and thereafter"

Kee-Bum Hong, MD[1,2], Chi-Hoon Oh, MD, PhD[3,#], Chae Kwang Lim, MD[1,2], Sungwoo Lee, MD[1,2], Soo-Hong Han, MD, PhD[3], Jun-Ku Lee, MD, PhD[1,2]

[1]Department of Orthopedic Surgery, National Health Insurance Service Ilsan Hospital, Goyang, Korea
[2]Department of Orthopedic Surgery, Yonsei University College of Medicine, Seoul, Korea
[3]Department of Orthopedic Surgery, CHA Bundang Medical Center, Seongnam, Korea

In the article titled "Does the operator's experience affect the occurrence of complications after distal radius fracture volar locking plate fixation? A comparative study of the first four years and thereafter" [1], the funding information was missing. The funding information, including the research/grant number can be found below.

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Reference

1. Hong KB, Oh CH, Lim CK, Lee S, Han SH, Lee JK. Does the operator's experience affect the occurrence of complications after distal radius fracture volar locking plate fixation? A comparative study of the first four years and thereafter. J Musculoskelet Trauma 2024;37:175-83.

Correction

Correspondence to:
Jun-Ku Lee, MD, PhD
Department of Orthopedic Surgery, National Health Insurance Service Ilsan Hospital, 100 Ilsan-ro, Ilsandong-gu, Goyang 10444, Korea
Tel: +82-31-900-0340
Email: jg197@naver.com

[#]Current affiliation: Department of Orthopedic Surgery, Korea University Ansan Hospital, Ansan, Korea

Instructions for authors

Enacted from January 1, 1988
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1. GENERAL INFORMATION

The *Journal of Musculoskeletal Trauma* is the official publication of the Korean Fracture Society. It is an international, peer-reviewed, open-access journal dedicated to advancing the science, education, and clinical care of musculoskeletal trauma. The journal was first launched in 1988 and is published quarterly on the 25th of January, April, July, and October. As of October 2024, the official language of the journal has been changed to English.

The journal covers a wide range of topics related to musculoskeletal injuries, including but not limited to: prevention, diagnosis, treatment, and rehabilitation of fractures, dislocations, and soft tissue injuries of both the extremities and the axial skeleton; advances in surgical techniques, implants, and prosthetic devices; biomechanical and biological research related to trauma and tissue healing; rehabilitation strategies for functional recovery; and clinical and translational research bridging basic science and clinical practice.

We invite submissions of original articles, reviews, letters to the editor, and editorial that contribute to the advancement of musculoskeletal trauma care. Manuscripts submitted to JMT should be prepared according to the following instructions. The journal adheres to the Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly Work in Medical Journals (http://www.icmje.org/) from the International Committee of Medical Journal Editors (ICMJE).

2. ARTICLE PROCESSING CHARGE

There are no author fees required for manuscript processing and/or publishing materials in the journal since all cost is supported by the publisher, the Korean Fracture Society until there is a policy change. Therefore, it is the so-called platinum open-access journal.

3. RESEARCH AND PUBLICATION ETHICS

The journal adheres to the guidelines for research and publication described in the Committee on Publication Ethics (COPE) Guidelines (https://publicationethics.org/resources/guidelines) the ICMJE Recommendations (https://www.icmje.org), and the Good Publication Practice Guideline for Medical Journals (https://www.kamje.or.kr/board/view?b_name=bo_publication&bo_id=13). Furthermore, all processes addressing research and publication misconduct shall follow the flowchart of COPE (https://publicationethics.org/resources/flowcharts). Any attempts to duplicate publications or engage in plagiarism will lead to automatic rejection and may prejudice the acceptance of future submissions.

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(Institute of Laboratory Animal Resources, Commission on Life Sciences, National Research Council). The authors should preserve raw experimental study data for at least 1 year after the publication of the paper and should present this data if required by the Editorial Board.

Protection of Privacy, Confidentiality, and Written Informed Consent

The ICMJE has recommended the following statement for the protection of privacy, confidentiality, and written informed consent: The rights of patients should not be infringed without written informed consent. Identifying details (patient's names, initials, hospital numbers, dates of birth, or other personal or identifying information, protected healthcare information) should not be published in written descriptions. Images of human subjects should not be used unless the information is essential for scientific purposes and explicit permission has been given as part of the consent. For individuals who cannot provide consent independently, including those from vulnerable populations—such as minors, the elderly, racial or ethnic minorities, individuals with certain health conditions, or those who are socioeconomically disadvantaged—consent should be obtained from a legally authorized representative or parent/guardian. Even where consent has been given, identifying details should be removed if they are not essential. If identifying characteristics are altered to protect anonymity, authors should provide assurances that such alterations do not distort scientific meaning. If consent has not been obtained, it is generally not sufficient to anonymize a photograph simply by using eye bars or blurring the face of the individual concerned.

Conflict of Interest

Authors are responsible for disclosing any financial support or benefit that might affect the content of the manuscript or might cause a conflict of interest. When submitting the manuscript, the author must attach a conflict of interest statement (https://e-jmt.org/authors/copyright_transfer_agreement.php). All authors should disclose their conflicts of interest, i.e., (1) financial relationships (such as employment, consultancies, stock ownership, honoraria, or paid expert testimony), (2) personal relationship, (3) academic competition, and (4) intellectual passion. These conflicts of interest must be included as a footnote on the title page. Each author should certify the disclosure of any conflict of interest with their signature.

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It is recommended that any research that deals with a clinical trial be registered with a clinical trial registration site, such as http://cris.nih.go.kr, or other primary national registry sites accredited by the World Health Organization (https://www.who.int/clinical-trials-registry-platform/network/primary-registries) or clinicaltrial.gov (http://clinicaltrials.gov/), a service of the United States National Institutes of Health.

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All papers, including those invited by the Editor, are subject to peer review. Manuscripts will be peer-reviewed by two accredited experts in the musculoskeletal trauma care with one additional review by prominent member of our Editorial Board. The editor is responsible for the final decision whether the manuscript is accepted or rejected.

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- JMT's average turnaround time from submission to decision is 4 weeks.
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- All articles in JMT include the dates of submission, revision, acceptance, and publication on their article page. No information about the review process or editorial decision process is published on the article page.

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The conflict of interest declaration should be added as follows.

Conflicts of Interest: OOO has been an Editorial Board member of *Journal of Musculoskeletal Trauma* since OOO but has no role in the decision to publish this article. No other potential conflicts of interest relevant to this article were reported.

Feedback after Publication

If the authors or readers find any errors or contents that should be revised, it can be requested from the Editorial Board. The Editorial Board may consider correction, or a retraction. If there are any revisions to the article, there will be a CrossMark description to announce the final draft. If there is a reader's opinion on the published article with the form of Letter to the editor, it will be forwarded to the authors. The authors can reply to the reader's letter. Letter to the editor and the author's reply may be also published.

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Any appeal against an editorial decision must be made within 2 weeks of the date of the decision letter. Authors who wish to appeal a decision should contact the Editor-in-Chief, explaining in detail the reasons for the appeal. All appeals will be discussed with at least one other associate editor. If consensus cannot be reached thereby, an appeal will be discussed at a full editorial meeting. The process of handling complaints and appeals follows the guidelines of COPE available from https://publicationethics.org/appeals. JMT does not consider second appeals.

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General Requirements

- All manuscripts should be written in English.
- The manuscript must be written using Microsoft Word and saved as ".doc" or ".docx" format. The font size should be 12 points. The body text must be left-aligned, double-spaced, and presented in a single column. The left, right, and bottom margins must be 3 cm, but the top margin must be 3.5 cm.
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- Systematic Review: Systematic review examines published material on a clearly described subject in a systematic way. There must be a description of how the evidence on this topic was tracked down, from what sources and with what inclusion and exclusion criteria.
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Table 1. Recommended maximums for articles submitted to JMT[a]

Type of article	Abstract (word)	Text (word)[b]	References	Tables & Figures
Original Article	Structured, 300	NL	30	NL
Review	Unstructured, 300	NL	NL	NL
Letter to the Editor	-	1,000	5	4
Editorial	-	1,000	10	4

[a]The requirements for the number of references, tables and figures and length of the main text can be consulted with the Editorial Office; [b]Excluding an abstract, tables, figures, acknowledgments, and references.

Format of Manuscript Title page

- The title page must include the title, the authors' names, academic degrees, affiliations, and the corresponding author's name and contact information. The corresponding author's contact information must include their name and email. In addition, a running title must be provided, with a maximum of 50 characters, including spaces.
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Each paper should begin with an abstract not exceeding 300 words (for original articles and reviews). The abstract for original articles should state the background, methods, results, and conclusions in each paragraph in a brief and coherent manner. Relevant numerical data should be included. Under the abstract, keywords should be provided (maximum of 5). Authors are encouraged to use the MeSH database to find Medical Subject Headings at http://www.nlm.nih.gov/mesh/meshhome.html. The structured abstract should be divided into the following sections.

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1. Song HK, Cho WT, Choi WS, Sakong SY, Im S. Acute compartment syndrome of thigh: ten-year experiences from a level I trauma center. J Musculoskelet Trauma 2024;37:171-4.
2. MacKechnie MC, Shearer DW, Verhofstad MH, et al. Establishing consensus on essential resources for musculoskeletal trauma care worldwide: a modified Delphi study. J Bone Joint Surg Am 2024;106:47-55.
3. Raats JH, Ponds NH, Brameier DT, et al. Agreement between patient- and proxy-reported outcome measures in adult musculoskeletal trauma and injury: a scoping review. Qual Life Res 2024 Aug 23 [Epub]. https://10.1007/s11136-024-03766-1

② Book & Book chapter

4. Townsend CM, Beauchamp RD, Evers BM, Mattox K. Sabiston textbook of surgery. 21st ed. Elsevier; 2021.
5. Meltzer PS, Kallioniemi A, Trent JM. Chromosome alterations in human solid tumors. In: Vogelstein B, Kinzler KW, eds. The genetic basis of human cancer. McGraw-Hill; 2002. p. 93-113.

③ Homepage/Web site

6. World Health Organization (WHO). World health statistics 2021: a visual summary [Internet]. WHO; 2021 [cited 2023 Feb 1]. Available from: https://www.who.int/data/stories/world-health-statistics-2021-a-visual-summary

④ Preprint

7. Sharma N, Sharma P, Basu S, et al. The seroprevalence and trends of SARS-CoV-2 in Delhi, India: a repeated population-based seroepidemiological study [Preprint]. Posted 2020 Dec 14. medRxiv 2020.12.13.20248123. https://doi.org/10.1101/2020.12.13.20248123

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July 1, 2012

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March 1, 2019

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