



# Open Reduction and Stable Internal Fixation Using a 3.5-mm Locking Hook Plate for Isolated Fractures of the Greater Tuberosity of the Humerus: A 2-Year Follow-up Study Using an Innovative Fixation Method

Woo-Yong Lee, MD, Hyun-Dae Shin, MD, Kyung-Cheon Kim, MD\*,  
Soo-Min Cha, MD, Yoo-Sun Jeon, MD, Dong-Hwan Kim, MD

Department of Orthopedic Surgery, Chungnam National University Hospital, Chungnam National University School of Medicine, Daejeon,  
\*Shoulder Center, Department of Orthopedic Surgery, TanTan Hospital, Daejeon, Korea

**Background:** The best treatment for isolated greater tuberosity (GT) fractures is still controversial. Although previous studies have suggested surgical options, they are either unable to provide firm fixation or present with a variety of complications.

**Methods:** We retrospectively studied the records of patients with isolated GT fractures who underwent open reduction and internal fixation using a 3.5-mm locking hook plate between January 2016 and January 2018. The surgical indication was an at least 5-mm displacement of the GT as observed in either simple radiography or three-dimensional computed tomography. Clinical outcomes were assessed using the following five parameters shortly before implant removal and at the final follow-up: visual analog scale (VAS) pain score, American Shoulder and Elbow Surgeons (ASES) score, Shoulder Rating Scale of the University of California, Los Angeles (UCLA), Constant-Murley score, and range of motion.

**Results:** Twenty-one patients with a mean age of 64 years were included. Bone union was achieved within 12–20 weeks of the first surgery in all patients. Implant removal was performed between 13 and 22 weeks after surgery. At the final follow-up, the mean VAS pain score, forward flexion, abduction, external rotation, internal rotation, ASES score, UCLA score, and Constant-Murley score were significantly better when compared to outcomes shortly before implant removal ( $p < 0.001$ ,  $p < 0.001$ ,  $p < 0.001$ ,  $p = 0.008$ ,  $p = 0.003$ ,  $p < 0.001$ ,  $p < 0.001$ , and  $p < 0.001$ , respectively).

**Conclusions:** The 3.5-mm locking hook plate provided sufficient stability and led to satisfactory clinical and radiological outcomes for isolated GT fractures. However, the hook plate may irritate the rotator cuff, and postoperative stiffness may be inevitable. Therefore, second surgery for implant removal is necessary after bone union is achieved.

**Keywords:** Greater tuberosity fracture, Proximal humerus, Olecranon, Hook plate, Rotator cuff

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Correspondence to: Yoo-Sun Jeon, MD

Department of Orthopedic Surgery, Chungnam National University Hospital,  
282 Munhwa-ro, Jung-gu, Daejeon 35015, Korea

Tel: +82-42-338-2480, Fax: +82-42-338-2482

E-mail: ooppss@hanmail.net

It is well known that the greater tuberosity (GT) of the humerus is one of the most important parts of the shoulder joint because it provides a footprint for the rotator cuff. Treatment of fractures of the GT is critical because malunion or displaced nonunion can lead to severe functional problems of the shoulder, such as limited range of motion (ROM) and impingement.<sup>1)</sup> Therefore, the treatment goal for fractures of the GT is to restore its anatomy with stable

fixation to recover shoulder function.<sup>2)</sup> The current consensus on the surgical indication for isolated GT fractures is a displacement of > 5 mm in the general population or > 3 mm in active, young patients. This is in contrast to the earlier recommendations reported by Neer,<sup>3)</sup> which were > 1 cm displacement or > 45° angulation.<sup>1,4-8)</sup> However, the optimal treatment for isolated GT fractures is still controversial although there have been reports on various surgical options since open reduction and internal fixation (ORIF) for acute GT fractures was first reported in 1907.<sup>9-19)</sup>

Proximal humeral fractures account for approximately 5% of all fractures.<sup>7)</sup> Of these, GT fractures account for approximately 20%.<sup>20,21)</sup> Most of the patients are elderly and have osteoporosis or osteopenia.<sup>22)</sup> Furthermore, the GT fragment is usually small or comminuted so it cannot be fixed securely with a plate or screws.<sup>7)</sup> Therefore, the surgical options for isolated GT fractures that have been reported could not provide firm fixation and presented with a variety of complications, which could lead to shoulder arthroplasty.<sup>23-25)</sup>

A 3.5-mm locking hook plate (DePuy Synthes, West Chester, PA, USA) can be used for fixation of the fractured or osteotomized olecranon.<sup>26)</sup> In the present study, the plate was used for fixation of the isolated GT fracture to provide stable fixation, which was achieved by the hook of the plate compressing the GT fragment. The aims of the present study were to introduce a new surgical technique and to evaluate clinical and radiological outcomes of ORIF using a 3.5-mm locking hook plate for isolated GT fractures.

## METHODS

This is a retrospective case series to introduce our new surgical technique and to evaluate clinical and radiological outcomes of ORIF using a 3.5-mm locking hook plate for isolated GT fractures. The Institutional Review Board of Chungnam National University Hospital approved the study and waived the need for informed consent from all patients (IRB No. CNUH 2019-10-031). We retrospectively reviewed the records of patients with isolated GT fractures who underwent ORIF using a 3.5-mm locking hook plate between January 2016 and January 2018 at our hospital. The surgical indication was an at least 5-mm displacement of the GT as observed in either simple radiography or three-dimensional computed tomography (3D CT) (Fig. 1). All fractures were assessed using anteroposterior, true anteroposterior, supraspinatus outlet, and axillary views throughout the follow-up period. 3D CT was performed on all patients to identify the location of displacement, the degree of comminution, and the morphological classifica-

tion of the GT fragment (avulsion, splint, or depression) according to Mutch et al.<sup>27)</sup>

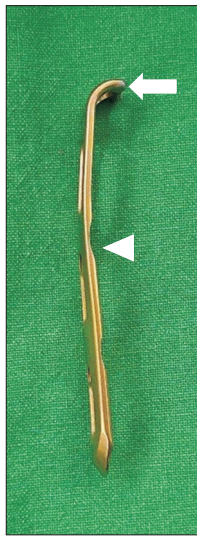
Exclusion criteria were (1) patients who were not available for the 2-year minimum follow-up after surgery, (2) patients with a history of any surgery in the affected shoulder, (3) patients with any concomitant injury requiring other surgery, (4) patients with a neurovascular injury before surgery, (5) patients with nonunion of the GT fracture, and (6) patients with immunocompromised disease, which may have affected bone union.

## Operative Technique

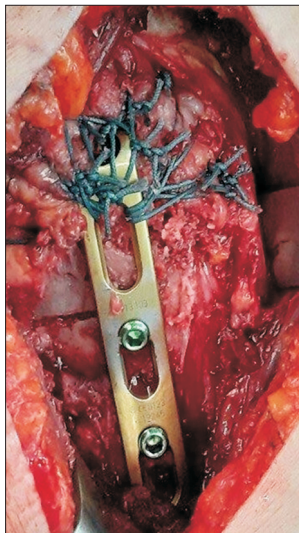
All patients were operated on by a single orthopedic surgeon (WYL) in a single hospital setting. With the patient under general anesthesia in the beach-chair position, the surgical procedure was performed using the deltopectoral approach. The fracture site was exposed and a heavy braided suture was placed into the supraspinatus tendon, which was attached to the GT fragment as a traction suture, then the fragment was reduced by pulling the suture in the anteroinferior direction. Reduction was confirmed with intraoperative radiographs, and subsequently, a 3.5-mm locking hook plate was positioned to match the contour of the plate and the reduced fracture. After the contour was identified, the plate was bent and the distal sharp part of the hook of the plate was cut and rasped off to prevent damage to the rotator cuff by the hook (Fig. 2). The fracture was reduced again, and the plate was applied. Then, the reduction and plate position were confirmed with intraoperative radiographs and the screws were inserted through the third and fourth screw holes. If



**Fig. 1.** A 30° caudal tilt view (A) and a supraspinatus outlet view (B) of the right shoulder of a 70-year-old female patient with a displaced and comminuted isolated fracture of the greater tuberosity of the humerus.



**Fig. 2.** The 3.5-mm locking hook plate is bent (arrowhead) to conform to the contour of the proximal humerus, and the distal sharp part of the hook of the plate is cut and rasped off (arrow).

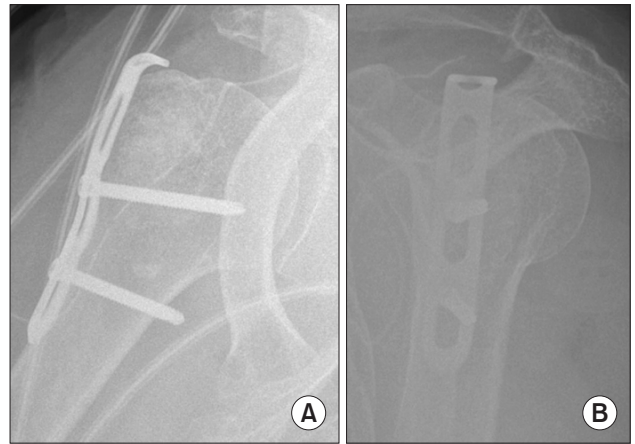


**Fig. 3.** An intraoperative gross photograph taken after augmentation tension suture fixation of an isolated fracture of the greater tuberosity of the humerus.

the fragment was too large to pass the screw in cases of a splint-type fracture or a large non-comminuted fragment, a cancellous screw was inserted through the second screw hole. Finally, augmentation tension sutures were fixed through the screw holes (Fig. 3). Postoperative radiography was performed to assess the fracture reduction and fixation (Fig. 4).

#### Postoperative Management and Implant Removal

All patients underwent standardized postoperative care.



**Fig. 4.** An immediate postoperative 30° caudal tilt view (A) and a supraspinatus outlet view (B) showing reduction of a displaced and comminuted isolated fracture of the greater tuberosity of the humerus.



**Fig. 5.** An immediate postoperative 30° caudal tilt view (A) and a supraspinatus outlet view (B) after implant removal.

The same treatment regimen was prescribed for all patients, regardless of the type of fracture or degree of comminution. Postoperatively, a shoulder-immobilizing brace with an abduction pillow was applied for 4 weeks. All patients accomplished gentle passive forward flexion arm exercises during the second postoperative week. The brace and abduction pillow were removed 4 weeks postoperatively, and passive ROM exercises in all directions and active mobilization were commenced.

All patients underwent a second surgery for implant removal because even if the distal shaft part of the hook was cut and rasped off, the hook would still irritate the rotator cuff, and postoperative stiffness would be inevitable. Furthermore, the hook might raise other problems in the rotator cuff, such as tendinitis or partial tears of the cuff.

The second surgery for implant removal was performed on all patients when union of the fracture was confirmed by radiography at 13–22 weeks after the first surgery. Post-operative radiography was performed immediately after the second surgery performed for implant removal (Fig. 5).

A simple sling without the pillow was applied for 2 weeks after the second surgery and passive ROM exercises in all directions were commenced simultaneously. Subsequently, active ROM mobilization was started. Resistance-based muscle-strengthening exercises were commenced 4 weeks after the second surgery using Thera-Band equipment (HCM-Hygenic Corp., Batu Gajah, Malaysia). At 8 weeks after the second surgery, patients were allowed to perform light activities, with participation in sports and heavy labor allowed at 12 weeks after the second surgery.

### Assessment and Statistical Analysis

We used dual-energy X-ray absorptiometry to measure the lumbar spine and femoral bone mineral density of all patients before fracture surgery. 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. To identify clinical outcomes after the first and second operations, the following parameters were assessed by an orthopedic surgeon (WYL) shortly before implant removal and at the final follow-up. We employed five outcome measures: visual analog scale (VAS) pain score, American Shoulder and Elbow Surgeons (ASES) score, Shoulder Rating Scale of the University of California, Los Angeles (UCLA), Constant-Murley score, and ROM. Pain was recorded using a VAS. Active ROM was measured using a goniometer and passive ROM was not measured. To identify the radiological union of the fracture, anteroposterior, true anteroposterior, supraspinatus outlet, and axillary views, and  $30^\circ$  caudal tilt views were obtained during follow-up.

All statistical analyses were performed using IBM SPSS ver. 20.0 (IBM Corp., Armonk, NY, USA). Clinical outcomes, which were evaluated shortly before implant removal and at the final follow-up, were compared using either the paired samples *t*-test or Wilcoxon signed-rank test based on normality of distribution according to the one-sample Kolmogorov-Smirnov test. A  $p < 0.05$  was considered statistically significant.

## RESULTS

Overall, 27 patients with isolated GT fractures underwent ORIF using a 3.5-mm locking hook plate. Among these, 6 patients were excluded based on the exclusion criteria: 2

patients were lost during follow-up, 1 patient underwent arthroscopic rotator cuff repair in the affected shoulder, 1 patient had concomitant fracture of the distal radius requiring surgery, 1 patient had axillary nerve injury due to dislocation at the time of trauma, and 1 patient had nonunion of the GT fracture due to trauma at 3 months. Finally, 21 patients (7 men and 14 women) with a mean age of 64 years (range, 42–82 years) were included. Of those, 12 patients had osteoporosis and 3 patients had osteopenia. There were 13 patients (61.9%) with dislocation, including 7 patients with the avulsion type and 14 patients with the split type. After metal removal, the final follow-up was performed at an average of 27 months (range, 24–36 months), and important demographic data of the study group are shown in Table 1.

Radiological union was achieved within 12–20 weeks in all patients. Implant removal was performed between 13 and 22 weeks after the surgery (Table 1). Shortly before implant removal, the ASES score was rated as good in 1 patient, fair in 7 patients, and poor in 13 patients; the

**Table 1.** Summary of Demographic Data

| Variable  | Variable   |
|---|------------|
| No. of patients                                 | 21         |
| Characteristics of patients                     |            |
| Age at surgery (yr)                             | 64 (42–82) |
| Male sex  | 7          |
| Osteoporosis                                    | 12         |
| Osteopenia                                      | 3          |
| Affected shoulder, right                        | 12         |
| With dislocation                                | 13         |
| Comminution of fracture                         | 12         |
| Type of fracture                                |            |
| Avulsion  | 7          |
| Split   | 14         |
| Depression                                      | 0          |
| Follow-up                                       |            |
| Time to union (wk)                              | 15 (12–20) |
| Time to second surgery for implant removal (wk) | 17 (13–22) |
| Developed rotator cuff tear                     | 2          |
| Duration of follow-up (mo)                      | 27 (24–36) |

Values are presented as number or mean (range).



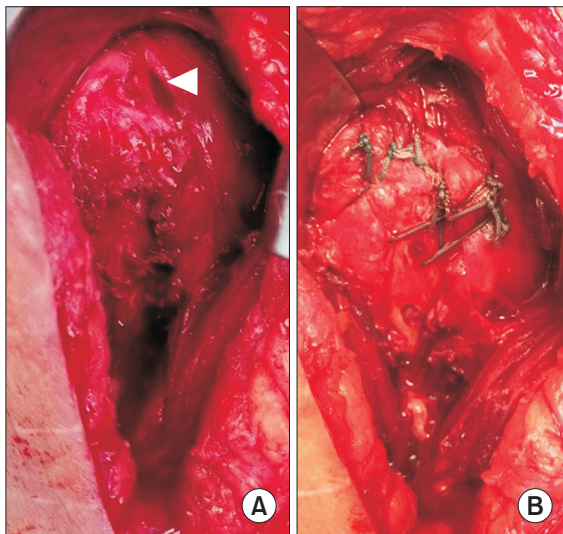
**Table 2.** Differences in Clinical Outcomes Shortly before Implant Removal and at the Final Follow-up

| Variable                           | Before implant removal | Final follow-up | <i>p</i> -value* |
|------------------------------------|------------------------|-----------------|------------------|
| VAS pain score                     | 4 (2–8)                | 1 (0–4)         | < 0.001          |
| Range of motion                    |                        |                 |                  |
| Forward flexion (°)                | 135 (90–170)           | 160 (110–180)   | < 0.001          |
| Abduction (°)                      | 120 (85–145)           | 155 (100–180)   | < 0.001          |
| External rotation (°)              | 62 ± 13.8              | 50 ± 14.8       | 0.008            |
| Internal rotation (level of spine) | L2 (L5–T7)             | T10 (L5–T4)     | 0.003            |
| Functional score                   |                        |                 |                  |
| ASES                               | 61 (28–83)             | 89 (57–100)     | < 0.001          |
| UCLA                               | 24 (15–31)             | 32 (20–35)      | < 0.001          |
| Constant-Murley                    | 73 (47–90)             | 94 (70–100)     | < 0.001          |

Values are presented as mean (range) or mean ± standard deviation.

VAS: visual analog scale, ASES: American Shoulder and Elbow Society, UCLA: University of California, Los Angeles.

\*Based on separate paired *t*-test or Wilcoxon signed-rank test; *p* < 0.05 denotes statistical significance.



**Fig. 6.** Intraoperative gross photographs taken after implant removal showing a bursal side partial-thickness tear of the rotator cuff (A, arrowhead) and the torn cuff repaired using a simple transosseous technique (B).

UCLA score was rated as good in 5 patients, fair in 11 patients, and poor in 5 patients; and the Constant-Murley score was rated as excellent in 1 patient, good in 5 patients, fair in 9 patients, and poor in 6 patients. However, at the final follow-up, the ASES score was rated as excellent in 11 patients, good in 8 patients, and poor in 2 patients; the UCLA score was rated as excellent in 9 patients, good in 10 patients, fair in 1 patient, and poor in 1 patient; and the Constant-Murley score was rated as excellent in 16

patients, good in 2 patients, and fair in 3 patients. At the final follow-up, the mean VAS pain score, forward flexion, abduction, external rotation, internal rotation, ASES score, UCLA, and Constant-Murley scores were significantly improved compared to outcomes shortly before implant removal ( $p < 0.001$ ,  $p < 0.001$ ,  $p < 0.001$ ,  $p = 0.008$ ,  $p = 0.003$ ,  $p < 0.001$ ,  $p < 0.001$ , and  $p < 0.001$ , respectively) (Table 2).

None of the patients had postoperative infections or any neurovascular complications after the surgery. However, damage of the rotator cuff occurred in 2 patients (9.5%) due to a bursal side partial thickness tear of the rotator cuff as a result of irritation by the hook, and these patients underwent repair of the tear using a simple transosseous technique (Fig. 6).

## DISCUSSION

By virtue of the development of rotator cuff repair, the understanding of the GT of the humerus has been advanced.<sup>28)</sup> As a result, the surgical indication for isolated GT fractures is currently > 5 mm dislocation, as opposed to the previous consensus, which was > 1 cm dislocation.<sup>1,3-8)</sup> However, treatment of GT fractures remains challenging and there is still debate about the numerous reported surgical modalities, such as plating, tension band wiring, cannulated screw fixation, and arthroscopic double-row suture anchor fixation.<sup>9-19)</sup>

The locking plate system is one of the most widely used fixation techniques for isolated GT fractures because of its stability. Gaudelli et al.<sup>29)</sup> reported that locking plate

fixation provides the strongest biomechanical fixation for split-type fractures compared to a tension band with no. 2 wire suture and double-row suture bridge with a suture anchor. However, there is a risk of splitting or further fragmentation and displacement of the fragment in elderly patients with osteoporosis or osteopenia.<sup>22,23)</sup> In the present study, 15 of 21 patients (71.4%) had osteoporosis or osteopenia, so in comminuted fractures or avulsion-type fractures with small fragments, the plate could not fix the fragment securely.<sup>18)</sup> In the present study, the avulsion type and comminuted fractures accounted for 7 (33.3%) and 12 (57.1%) of 21 patients, respectively. These issues correspond not only with the locking plates for the proximal humerus, but also with other types of plates, such as mini locking plates or mesh plates.<sup>18,19)</sup>

Tension band wiring is one of the conventional techniques for fractures, but it is associated with several problems. It is less likely to provide accurate reduction of the tuberosity in comminuted fractures because of its tensile force.<sup>18)</sup> In addition, tunnel drilling in fixation wiring could lead to other complications, such as cortical breakage and reduction loss, especially in elderly patients with osteoporosis or osteopenia.<sup>18)</sup>

Cannulated screw fixation is another treatment option for isolated GT fractures. It is a relatively simple and time-saving procedure, but it cannot be applied for comminuted fractures, and relatively long immobilization periods are needed, which cause postoperative stiffness because of the lack of solid fixation.<sup>30)</sup> In addition, there is the risk of further comminution because of the screws passing the GT fragment.<sup>12)</sup>

Arthroscopic double-row suture anchor fixation was introduced and its outcomes have been reported recently.<sup>2,7,11,12,18,22,28,31)</sup> It can be evaluated and treated with an associated injury of the glenohumeral joint or subacromial space without the need for removal of the implant and it provides more stable fixation than a screw or plate in comminuted fractures.<sup>2,12)</sup> However, the arthroscopic technique is a more technically demanding procedure and requires a longer surgical time.<sup>12,30)</sup> Furthermore, it cannot be applied to patients with a fracture line extending near the bicipital groove or the surgical neck of the humerus.<sup>2,12,30)</sup> In addition, when the anchor is pulled out in elderly patients with osteoporosis or osteopenia, the procedure can damage the rotator cuff because the medial anchors were inserted and the sutures were passed through the cuff, which was attached to the GT fragment.<sup>12,31)</sup>

In the present study, the 3.5-mm locking hook plate provided strong stability even in patients with osteoporosis or osteopenia and those with comminuted fractures or

small fragments. There was no case with nonunion or loss of reduction in our study. There are several reasons why the fixation was more stable than that in other techniques. First, the fracture was not fixed by the screw through the hole of the plate, and therefore, there was no risk of a split or further fragmentation and displacement of the fragment because of the screws passing the GT fragment. Second, the hook plate had the same effect as a buttress plate supporting the fragment. Additionally, the hook of the plate prevented displacement, especially superiorly. Third, the 3.5-mm locking hook plate is a locking plate. Therefore, it is more secure than other techniques that use suture anchors or cannulated screws.<sup>11,12,30,31)</sup>

However, the hook may cause problems with the rotator cuff, such as tendinitis or partial tears because the hook of the plate irritates the rotator cuff. Two patients with rotator cuff injury underwent repair surgery at 20 weeks and 22 weeks after the latest metal removal. Metal removal was performed at an average of 17 weeks, and the remaining patients had no rotator cuff injury. Due to this issue, a second operation for removal of the implant is necessary immediately after bony union.

Some limitations of the present study should be noted. First, the number of included patients was small, so comparative studies involving a follow-up of a larger number of patients are needed in the future. Second, there was no comparative group because the present study introduced a new technique for isolated GT fractures. The authors are currently collecting and evaluating data for comparison with other techniques for the next research study. Third, the present study was a retrospective study; however, the study had a homogenous patient group given the strict inclusion criteria. Moreover, patients were immobilized for 4 weeks after the first surgery because we performed this surgical procedure for the first time. Immobilization may be unnecessary due to the rigid fixation by the plate. Research on rehabilitation will be needed.

In conclusion, the 3.5-mm locking hook plate provided sufficient stability for isolated GT fractures and led to satisfactory clinical and radiological outcomes. However, the hook of the plate irritates the rotator cuff and thus postoperative stiffness may be inevitable. Therefore, a second surgery for implant removal is necessary after bone union is obtained.

## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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## ORCID

Woo-Yong Lee <https://orcid.org/0000-0001-8706-6026>  
 Hyun-Dae Shin <https://orcid.org/0000-0003-4290-1125>  
 Kyung-Cheon Kim <https://orcid.org/0000-0002-8874-2628>  
 Soo-Min Cha <https://orcid.org/0000-0003-1663-406X>  
 Yoo-Sun Jeon <https://orcid.org/0000-0003-4391-0349>  
 Dong-Hwan Kim <https://orcid.org/0000-0002-9320-0153>

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