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Original Article

Trochanteric Claw Plate Fixation for Greater Trochanteric Fracture or Osteotomy in Total Hip Arthroplasty

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This study retrospectively evaluated 41 consecutive open reductions and internal fixations following primary or revision total hip arthroplasty, which required trochanteric claw plate fixation for greater trochanteric fracture or osteotomy between January 2008 and December 2020. The mean duration of clinical follow-up was 4.2 years (range, 1-13 years). The patients included 13 men and 28 women, with a mean age of 68 years (range, 32-87 years). The indications for intervention included trochanteric osteotomy, intraoperative fracture, and non-union including postoperative fracture in 6, 9, and 26 cases, respectively. The mean Merle d'Aubigné Clinical Score improved from 9.4 points (range, 5-15 points) pre-operatively, to 14.3 points (range, 9-18 points) at the last follow-up. Bone union occurred in 35 cases (85%), while implant breakage occurred in four cases. At the last follow-up, the mean Merle d'Aubigné Clinical Scores of bone union and non-union were 15.3 and 14.1, respectively ($p = 0.48$). The Kaplan-Meier survival rate, with the endpoint being revision surgery for pain, non-union, dislocation, or implant breakage, at 10 years was 80.0% (95% confidence interval: 62.6-97.4%). Greater trochanteric fixation using a trochanteric claw plate yielded successful results.

Key words: greater trochanteric fracture, trochanteric osteotomy, claw plate, total hip arthroplasty

Periprosthetic fractures (PPFs) that occur intra- and postoperatively following total hip arthroplasty (THA) result in considerable morbidity and dysfunction in patients [1,2]. The number of PPFs is increasing, and currently PPF is the third most common reason for revision surgery in the US and the second in the UK [3,4] [National Joint Registry 2020. https://reports.njrcentre.org.uk/hips-revision-procedures-patient-characteristics/H19v1NJR?reportid=AB5D4468-323C-4E54-8737-11C7DAA7B75E&defaults=DC__Reporting_Period__Date_Range=%22MAX%22,J__Filter__Calendar_Year=%22MAX%22,H__Filter__Joint=%22Hip%22 (accessed September 25, 2022.)]. Although greater trochanter fracture (Vancouver type A_G) is the most common type of PPF, there are fewer studies of Vancouver type A_G compared to Vancouver type B and C fractures [5,6]. Vancouver type A_G fractures are often neglected because greater trochanter fractures that are minimally displaced and considered stable have historically been treated nonoperatively. However, a greater trochanter fracture involving the abductor lever arm can be a devastating complication leading to persistent pain, a Trendelenburg gait pattern, chronic dislocation, and reduced quality of life. The indication for fixation of the ununited greater trochanter following THA depends largely on functional impairment and the magnitude of proximal migration of the trochanteric fragment [7]. Hence, the indications for fixation after trochanteric osteotomy is

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also similar to those after a greater trochanter fracture.

Trochanteric fractures or non-unions remain a challenging problem. Moreover, there are several technical difficulties involved in their resolution, including the small size of the bone fragment, which is an important site for the gluteus medius muscle attachment, and requires fixation with muscle. Although various methods for trochanteric fixation have been developed, the most common being monofilament wires, multifilament braided cables, cable-plate systems, or locking plates, it is difficult to support the use of one implant over another [8]. Nonetheless, at our institution, we have usually used a trochanteric claw plate (CMK Trochanteric plate; Zimmer Biomet Holdings Inc., Warsaw, IN, USA) for greater trochanteric fracture or osteotomy following THA. A trochanteric claw plate has the following advantages: (1) the large hooks allow bone fragments to be captured with muscles, (2) there is less irritation because no screw fixation is required around the greater trochanter, and (3) the plate can be bi-cortically fixed at the diaphysis. This study was designed to reintroduce this technique and retrospectively evaluate the clinical results. We hypothesized that the trochanteric claw plate would be effective for the fixation of the greater trochanter.

Materials and Methods

This single-center observational study was approved by our institutional review board (2021152), and it adhered to the Declaration of Helsinki. All patients provided informed consent for participation and publication of findings.

Patients. Forty-six consecutive open reductions and internal fixations (ORIFs) following primary or revision THA, which required fixation using a trochanteric claw plate for greater trochanteric fracture or osteotomy, were performed at our institution between January 2008 and December 2020. Of these, 5 patients (5 hips) were lost to follow-up (follow-up rate, 89%). The remaining 41 subjects were 13 men and 28 women, with a mean age of 68 years (range, 32-87 years) at the time of surgery. The mean duration of clinical follow-up was 4.2 years (range, 1-13 years). The trochanteric claw plate was used for trochanteric osteotomy (namely Charnley's osteotomy) in 6 hips, intraoperative fracture in 9 hips, and non-union including postoperative fracture in 26 hips (Table 1). Non-union included dislocation in 8 hips, pain in 4 hips, transposition of fragment in 2 hips, limp in 1 hip, and fixation of the existing displaced trochanteric fragment from unrelated revision in 11 hips. In 26 cases of non-union including postoperative fracture, the original approach was Dall in 14, posterior in 6, trochanteric osteotomy in 3, and post ORIF in 3. The indication for managing an ununited greater trochanter was decided according to Hamadouche's algorithm, primarily based on the degree of limp, the magnitude of proximal migration of the greater trochanter, and pain (Fig. 1) [7].

Surgical procedure. The trochanteric claw plate characteristics are as follows: 1) the proximal end has two hooks that capture the trochanteric fragment, and 2) the distal end has two convex flanges that are apposed to the femoral cortex (Fig. 2) [7,9,10]. In addition, each of these arms has one hole for flexible fixation to the femur with a 4.5 mm screw. The device is available in three sizes (80 mm, 90 mm, and 100 mm).

The transgluteal approach in the lateral position was used in all the patients. Furthermore, in revision THA, a longitudinal incision was made after incision through the skin and tensor fascia latae. Dislocation of the prosthesis was usually not required, and the trochanteric fragment and its femoral bed were cleaned of all fibrous or granulation tissue. Although the fixation of the trochanteric claw plate was performed according to previ-

Table 1 Pre-operative patient characteristics

Patient Demographics	Value
Number of hips	41
Mean age at surgery, years (range)	68 (32–87)
Sex, male: female	13 : 28
Mean body mass index, kg/m^2 (range)	22.5 (13.8–29.6)
Average number of previous operation, times (range)	1.3 (0–3)
Type of previous implant, cement: cementless: ORIF	26 : 12 : 3
Mean follow-up period, years (range)	4.2 (1–13)
Reason for the use of a trochanteric claw plate	
Trochanteric osteotomy	6
Intra-operative fracture	9
Non-union including post-operative fracture	26

ORIF, open reduction and internal fixation.

ous reports [7, 9, 10], we augmented the claw plate with an ultra-high molecular weight polyethylene fiber cable (UHMWPE fiber cable; NESPLON Cable System, Alfresa Pharma Co., Osaka, Japan) [11, 12]. The hooks were pushed into the thickness of the gluteus medius tendon until they were in anterior contact with the trochanteric fragment. The claw plate in close contact with the trochanteric fragment was pulled down in the distal direction, and the vastus lateralis was longitudinally incised to expose the subtrochanteric region. The UHMWPE fiber cable was circled around the claw plate. The plate was pulled down in the distal direction at the position with 20° of abduction, and then a 2.0 mm Kirshner wire was temporally fixed into the distal central hole. In cases of instability between the hooks and trochanteric fragment, a second UHMWPE fiber cable was circled over the hooks and trochanteric fragment. After the temporal fixation, the UHMWPE fiber cable was firmly tightened to a tension strength of approximately 20 kg. The cable was tied using a tensioning device (Alfresa Pharma Co.) with a double loop-sliding knot technique [13]. The fixation was then completed with two 4.5 mm bi-cortical screws placed anteriorly and posteriorly to the femur (Fig. 3). In our experience, the screw was sometimes fixed only in the posterior hole because the anterior femoral bone is narrow. Finally, the temporal Kirschner wire was removed, and the rigidity of the fixation was confirmed. Full weight-bearing was allowed as soon as possible, although the patients were encouraged to use a cane for up to 3 months.

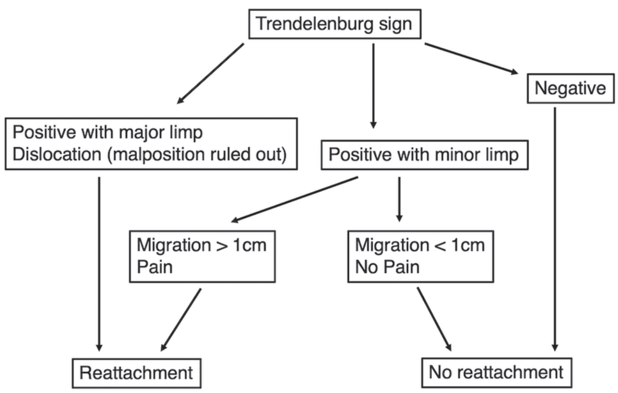

Fig. 1 Treatment algorithm for non-union of the greater trochanter following total hip arthroplasty according to Hamadouche *et al*. [7].

Fig. 2 Photograph of the trochanteric claw plate (size: 80 mm). The proximal end of the trochanteric claw plate has two hooks that capture the trochanteric fragment, and its distal end has two convex flanges that are apposed to the femoral cortex.

Measurements. After surgery, patients were followed-up at 2 weeks, 3 months, 6 months, 1 year, and annually thereafter. A retrospective analysis was performed by two blinded orthopedic surgeons. For clinical assessment, the Merle d'Aubigné and Postel grading system was used preoperatively and at the last follow-up [14]. Intraoperative and postoperative complications were also recorded. For radiological assessment, anteroposterior radiographs of the pelvis were evaluated using a ruler (Carestream Health Japan Co., Tokyo). Global offset was calculated from the horizontal dis-

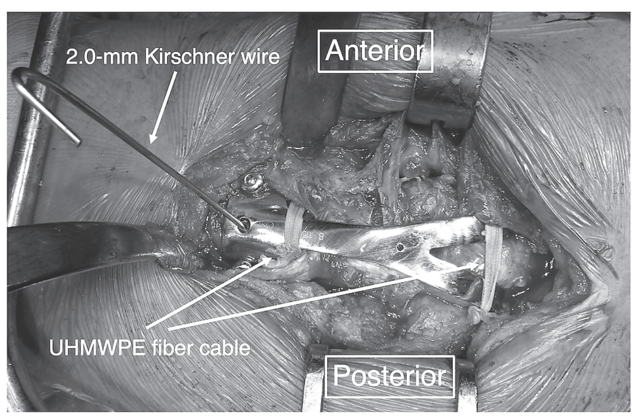

Fig. 3 Intraoperative photograph of the left hip in the lateral position. An ultra-high molecular weight polyethylene (UHMWPE) fiber cable is circled around the femur with the claw plate, and another fiber cable is circled over the hooks and trochanteric fragment.

tance between the vertical midline and lateral femoral cortex, and the lateralization was defined as the post-operative global offset divided by the pre-operative global offset [15]. Trochanteric non-union was defined as visible migration of the trochanter. Union was considered to be complete when no residual radiolucent line was visible on the most recent anteroposterior views of the radiograph [9]. The apposition was considered good if the contact was perfect and there was no gap, fair if the gap was <3 mm, and poor if it was ≥ 3 mm [7].

Statistical analysis. Statistical analysis was performed using Student's t-test, with a p-value <0.05 considered statistically significant. Prosthesis survival was determined using the Kaplan -Meier method with 95% confidence intervals; end points were repeat revision surgery for implant breakage, non-union, dislocation, or pain. Data were analyzed using SAS 9.2 (SAS Institute Inc., Cary, NC, USA).

Results

The mean Merle d'Aubigné Clinical Score improved from 9.4 points (range, 5-15 points) pre-operatively to 14.3 points (range, 9-18 points) at the last follow-up ($p<0.05$) (Table 2) (Fig. 4). With respect to abductor weakness, the mean active abductor range increased from 10.4° (range, 0-20°) pre-operatively to 22.8° (range, 5-40°) at the last follow-up ($p<0.05$). Repeat revision surgery was performed in 8 patients for the following indications: pain in 4 hips (10%), periprosthetic fracture in 2 hips (5%), recurrent dislocation in 1 hip (2%), and periprosthetic infection in 1 hip (2%). Four patients who experienced an implant breakage were treated nonoperatively because of the absence of symptoms. There was no obvious difference between patients with and without pain (Table 3).

Bone union occurred in 85% of patients (35/41 cases), with a mean duration of 1.4 years (range, 0.3-5

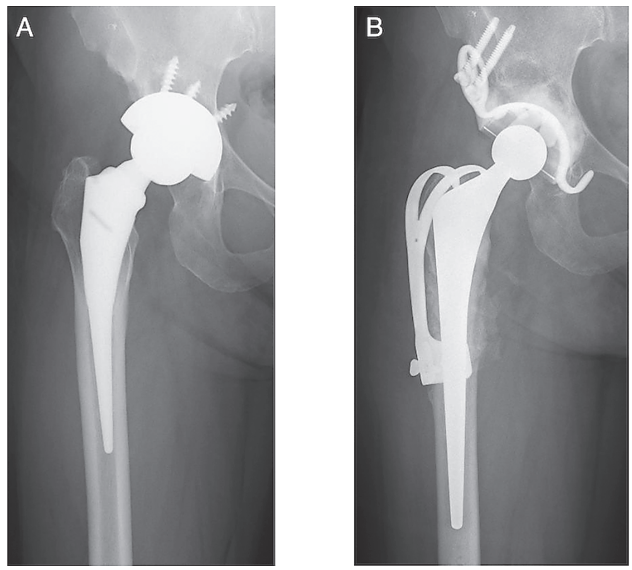

Fig. 4 Anteroposterior radiographs of a 54-year-old woman in whom a trochanteric claw plate was used for intra-operative fracture in a one-stage revision total hip arthroplasty (THA) because of periprosthetic infection. (**A**) The primary THA was performed for secondary osteoarthritis 3 years prior. (**B**) At 2 years after revision THA.

Table 2 Mean Merle d'Aubigné Clinical Score

Demographics	Preoperative	Last follow-up	*P*-value*
All cases (41 cases)			
Total	9.4 ± 2.9	14.3 ± 2.3	<0.0001
Pain	2.6 ± 1.2	5.3 ± 0.8	<0.0001
Mobility	4.4 ± 1.4	5.2 ± 1.1	<0.0001
Ability to walk	2.4 ± 1.4	3.8 ± 1.8	<0.0001
Reason for the use of a trochanteric claw plate			
Trochanteric osteotomy (6 cases)	7.0 ± 1.3	14.2 ± 3.3	0.0018
Intra-operative fracture (9 cases)	7.3 ± 2.1	13.8 ± 2.1	<0.0001
Non-union (26 cases)	10.9 ± 2.6	14.7 ± 2.2	<0.0001
Bone union at the last follow-up			
Non-union (6 cases)	9.6 ± 2.9	15.3 ± 2.8	0.0488
Union (35 cases)	9.3 ± 2.9	14.1 ± 2.2	<0.0001

Values are expressed as mean ± standard deviation or number. *Student's *t*-test.

years). The rates of bone union in trochanteric osteotomy, intraoperative fracture, and non-union were 100% (6/6), 78% (7/9), and 85% (22/26), respectively. Details are shown in Table 4 for 6 patients without bone-union. All patients without bone-union were revision cases. In terms of postoperative bone contact, 20 hips were categorized as good, 8 as fair, and 13 as poor. At the last follow-up, the mean Merle d'Aubigné Clinical Scores of bone union and non-union were 14.1 and 15.3, respectively ($p=0.48$). The 10-year survival rate, with the endpoint being revision surgery for pain, non-union, dislocation, or implant breakage, was 80.0% (95% confidence interval, 62.6-97.4%).

Discussion

In recent years there has been an increase in PPF incidence worldwide, with the cumulative probability being 3.5-4.0% [1,3,4,6]. The reason may be that the excellent results with THA have led to expanded indications for the procedure, including younger and more active patients, and more elderly patients [16]. Vancouver's classification is most commonly used for categorizing PPFs [5]. Type A fractures involve the trochanteric region and are subclassified into factures of the greater and lesser trochanter, or A_G and A_L fractures, respectively. Type B fractures are those around the stem, or slightly distal to the stem. Type C fractures are distal to the stem. Type B fractures are subclassified into B1 when the implant is stable, B2 when the implant is unstable, and B3 when the bone stock is inadequate. B2 and B3 fractures require revision to a longer stem, while B1 and C fractures can be commonly fixed with a locking plate. Although there are

Table 3 Patients with and without pain following trochanteric claw plate fixation

	With pain (n=4)	Without pain (n=37)
Average age	51.8 ± 18.4	69.8 ± 12.1
Average BMI (kg/m^2)	23.1 ± 3.1	22.3 ± 3.4
Average number of previous operation (times)	1.0 ± 0	1.3 ± 0.8
Average lateralization (%)	−1.5 ± 0.7	−0.9 ± 0.9

Values are expressed as mean ± standard deviation or number.
BMI, bone mass index.

Table 4 Patients without bone-union following trochanteric claw plate fixation

Case	Age/Sex	BMI	Reason for the use of claw plate	Number of previous operation (times)	Type of previous operation and approach
1	54/F	23.3	Intra-operative fracture in revision	1	Cementless THA Mini-one
2	74/F	25.3	Intra-operative fracture in revision	1	Cementless THA Posterior
3	51/F	20.4	displaced trochanteric fragment from unrelated revision	1	ORIF Lateral
4	73/M	17.0	displaced trochanteric fragment from unrelated revision	1	Cement THA Dall
5	72/F	25.0	displaced trochanteric fragment from unrelated revision	2	Cement THA Charnley
6	75/F	23.5	Dislocation after non-union	1	Cement THA Dall

BMI, bone mass index; THA, total hip arthroplasty; ORIF, open reduction and internal fixation.

more reports of Vancouver type B or C fractures than of Vancouver type A_G fractures, Vancouver type A_G fractures are actually the most common type, accounting for 32.1% of PFFs [6]. Greater trochanter fractures mostly occur without trauma; they are avulsion-type fractures treated non-operatively. However, the ununited greater trochanter following THA depends mainly on functional impairment and the magnitude of the proximal migration of the trochanteric fragment that requires fixation [7].

Fixations of the trochanteric fracture and non-union remain a challenge because the bone fragment is usually small, despite being an important site for the attachment of the gluteus medius muscle. Various methods for trochanteric fixation after trochanteric fracture or osteotomy have been developed. Mei *et al.* [8] systematically reviewed 10,956 fixations following greater trochanteric osteotomies and fractures, and reported that non-union occurred in 4.2% of cases following the use of a wire, in 5.1% of cases using a cable, in 16.2% of cases using a cable-plate system, in 9.6% of cases using a claw or locking plate, and in 12.4% of cases using a trochanteric bolt. However, while this systematic review included some reports of other types of "claw plates", the use of a trochanteric claw plate with the same concept as that used in our current study has only been reported in Cochin Hospital in France [10]. To the best of our knowledge, few of the methods without a trochanteric claw plate have yielded favorable results, including with respect to non-union, function, or pain. Trochanteric claw plate fixation is especially well suited in cases with a small trochanteric fragment. Hamadouche *et al.* [10] reported that non-union of the trochanteric claw plate occurred in 17% of their patients, only trochanteric claw plate in 25%, and trochanteric claw plate augmented with vertical wires in 0%. The quality of postoperative bone contact and the use of vertical wires were associated with a higher rate of union, and these two factors were not independent variables. Subsequently, Vastel *et al.* [9] also concluded that the unwanted effects of non-union can be minimized by trochanteric claw plate fixation, which significantly improves final hip function, even in cases of non-union of the greater trochanter. In our present study, the large hooks of a trochanteric claw plate sometimes resulted in postoperative pain, because the trochanteric claw plate was initially designed for repairing non-union of the greater trochanter [17]. Although the risk factors of pain and non-union could not be identified, the greater trochanteric fixation using a trochanteric claw plate after trochanteric fracture or osteotomy yielded successful results. However, unlike screw fixations, the hooks of a trochanteric claw plate are not strongly fixated (Table 5). Hence, it is essential to augment the trochanteric claw plate with UHMWPE fiber cables or other wires.

The incidence of trochanteric fracture and non-union is known to be related to the surgical approaches in THA. Charnley popularized the use of trochanteric osteotomy, which was routinely performed in primary THA in 1960 and 1970 [18]. Currently, trochanteric osteotomy is sometimes used for complex primary and revision THA. The reported rate of non-union following trochanteric osteotomy using steel wires ranges from 0.4% to 21% [19]. Consequently, many different wiring techniques have been developed. A trochanteric claw plate was developed to deal with non-union of the greater trochanter by Courpied at Cochin Hospital [17]. In addition, Dall [20] described the modified direct lateral approach, which retains a trochanteric bone fragment within the connection between the gluteus medius and vastus latralis. This approach is called a partial trochanteric osteotomy. The reported rate of radiological complications after the modified Dall's approach was 13%, although it required no revision for dislocation or limp [21]. Surgeons who routinely use a trochanteric osteotomy or its modifications may have more experience with the fixation of non-union of the greater trochanter because they may encounter non-union following the osteotomy in practice. Currently, greater trochanteric fractures resulting from THA with a direct anterior approach (DAA) are not rare, occurring in approximately 29% of cases [22]. This is because the greater trochanter is sometimes subjected to excessive load and stress due to the surgical procedure of

Table 5 Advantages and risks of fixation using a trochanteric claw plate

Advantages
(1) Large hooks allow a bone fragment to be captured with muscles
(2) No screw fixation around greater trochanter causes less irritation
(3) Plate can be bi-cortically fixed at the diaphysis
Risks
(1) Hook itself is not fixated strongly
(2) Large hooks sometimes result in postoperative pain

lifting the femur to prepare for stem installation during surgery. There is no consensus on the treatment of greater trochanteric chip fractures following DAA. Intrinsically, post-operative fracture may be caused by intra-operative iatrogenic damage.

There were some limitations to this study. First, we retrospectively evaluated the patients without a control group; all the analyzed patients underwent the current technique. Furthermore, our follow-up period was limited to a minimum of one year. Continued follow-up will be required to establish the long-term outcomes of this procedure. Second, the sample size was relatively small, involving only 41 individuals. In addition, patient-reported outcomes were not evaluated, and a relatively old assessment was used. Third, all operations were performed by high-volume surgeons; the outcomes might have been difficult if the operations had been performed by less-experienced surgeons. In addition, we routinely used a modified Dall's approach in the primary THA and had some technical knowledge of the non-union of the greater trochanter.

In conclusion, greater trochanteric fixation using a trochanteric claw plate yielded successful results, even though some patients had non-union of the greater trochanter. However, some patients experienced pain and implant breakage following the fixation of a trochanteric claw plate.

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