Outcomes Following Reduction of Sanders Type III/IV Calcaneal Fracture Using Impaction Technique and Ligamentous Sparing

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Purpose: *To demonstrate the outcomes of the impacted reduction technique with plating fixation for Sanders type III-IV calcaneal fractures, without detaching the calcaneofibular and talocalcaneal ligaments.*
Methods: *Retrospective analysis of the calcaneal fractures Sanders type III-IV, which were treated with impacted reduction technique and plate fixation during January 2012 to December 2016 was conducted. Medical records and radiographies were reviewed for collecting demographic data and radiographic parameters. Pre-operative and post-operative radiographic parameters were compared.*
Results: *Twenty-seven consecutive calcaneal fractures were evaluated, in which 22 fractures (81.5%) were classified as Sanders type III, underwent the operative treatments at 14.8 days (range, 10-18 days). The impacted reduction technique was able to post-operatively restore the Bohler, Gissane, and varus angles, and the articular stepping from 8.2 (±17.3) to 27.2 (±4.8) degrees, with a mean difference of 19.0 (±17.2) degrees; 99.2 (±14.4) to 126.7 (±7.1) degrees, with a mean difference of 27.6 (±14.1) degrees; 7.3 (±3.6) to 4.4 (±1.1) degrees, with a mean difference of -3.0 (±3.2) degrees; and 4.3 (±0.9) to 0.7 (±0.7) millimeters, with a mean difference of -3.5 (±1.1) millimeters, respectively; with a statistically significant difference (P<0.001). Mean of the estimated blood loss, operative times, and union times were 78.7 milliliters, 99.2 minutes, and 3.5 months, respectively.*
Conclusion: *The impacted reduction technique for Sanders type III-IV calcaneal fractures improved the restoration of the post-operative Bohler angle, Gissane angle, varus malalignment, and articular stepping radiographic parameters.*
Level of study: *Level IV case series.*

Keywords: *Calcaneal fracture, reduction technique, impacted reduction*

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Introduction

The calcaneal fracture is one of the common fractures caused by high-energy injuries, and almost is the intra-articular type[1]. The displaced intra-articular fracture types, especially Sanders type II-IV, usually require both operative reduction and internal fixation. The aim of open reduction is to anatomically restore the radiographic parameters[2,3]. These parameters have an effect on the long term outcomes of treatment, including post-traumatic subtalar arthrosis and functional recovery[4-6]. The traditional technique for operative fixation in a displaced intra-articular calcaneal fracture is anatomical lateral plating, via the extensile lateral approach[7-9].

This conventional surgical approach requires the detaching of the calcaneofibular and talocalcaneal ligaments, in order to reveal the reduction articular fragments. Both of these ligaments have an important role in ankle stability. The calcaneofibular ligament is the main restraint of the ankle in an inversed position, and the talocalcaneal ligament has a significant effect on subtalar joint stability[10-13]. The purpose of this study, therefore, is to demonstrate the technique and outcomes of intra-articular calcaneal fracture treatment via the impacted reduction technique and anatomical lateral plating under fluoroscopic assistance - without detaching these ligaments.

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Materials and Methods

Consecutive cases of calcaneal fracture, classified via computed tomographic scanning as Sanders type III and IV[14], which had undergone operative fixation with the impacted reduction technique and anatomical lateral plating at Khon Kaen Hospital, from January 2012 to December 2016; were evaluated for demographic data and radiographic parameters. Inclusion criteria included patients age of 18 years and over, had an acute closed displaced intra-articular fracture (Sanders type III and IV), and had undergone

operative treatment with the impacted reduction technique and anatomical lateral calcaneal plating within one month of injury. Exclusion criteria were multiple injuries, previous medical history that had effect on bone healing process, as well as any inadequate data from the medical records or radiographic examinations. All operations were performed by a single surgeon (WP), after soft tissue swelling had subsided or wrinkle sign was presented.

Operative technique

The patient was positioned in lateral decubitus, and a pneumatic tourniquet was applied with the appropriate pressure for reducing intraoperative blood loss. The initial conventional surgical approach was performed under the extensile lateral exposure technique, until most of the calcaneal lateral cortex was revealed (Fig. 1D, E). A full-thickness lateral flap was created and the calcaneofibular and talocalcaneal ligaments were meticulously preserved (Fig. 1F). The lateral cortical wall of the calcaneus was elevated in order to approach the depressed intra-articular fragments and subchondral area. The intra-articular fragments were reduced under impaction technique with a bone impactor, under fluoroscopy. An unacceptable Gissane angle, displaced posterior facet fragments, or articular incongruency were corrected in this step (Fig. 2A). Large pieces of hydroxyapatite were filled in the subchondral bony defect, for supporting of the articular reduction (Fig. 2B, C). A large posterior percutaneous pin was simultaneously inserted for restoration of the Bohler angle and correction of the varus malalignment (Fig. 2D). The anatomical lateral locking calcaneal plate was properly placed and fixed (Fig. 2E, F), followed by conventional Radivac® drain placement and skin closure.

Outcome measurement and statistical analysis

Demographic data of all participants, type of fracture, day of operation, estimated intra-operative blood loss and operative times were retrospectively collected from medical records. Pre- and post-operative radiographic parameters, including Bohler angle, Gissane angle, articular stepping, and varus angle, were measured (Fig. 3) and compared for statistically significant difference with a paired T-test. Union time was determined from the duration post-operation to the day of the radiographic union.

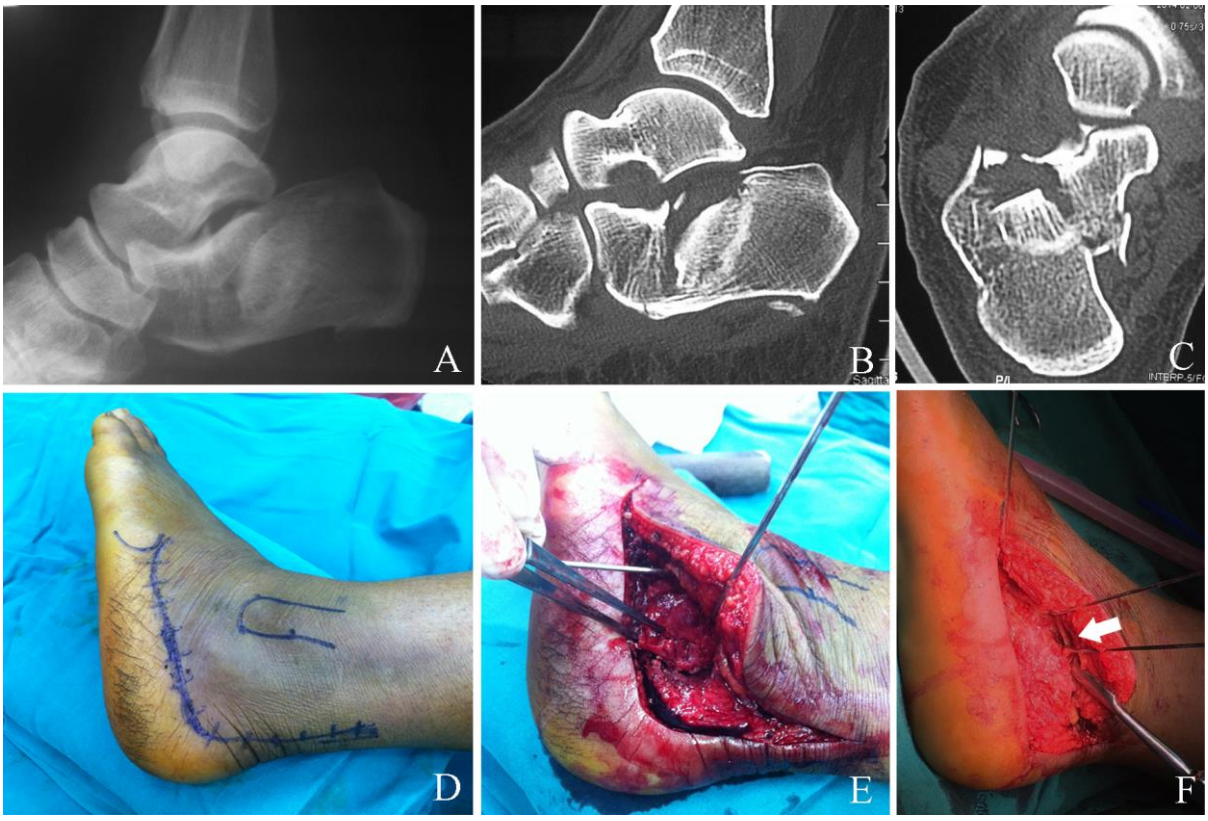

Fig. 1 A case of calcaneal fracture, Sanders type III, presented with loss of Bohler angle, Gissane angle, and incongruence of the articular surface (A-C). Surgical treatment began with the lateral decubitus positioning of the patient, followed by a skin incision in lateral L-shape fashion (D). A single layer of skin and subcutaneous tissue flap was developed for exposing the lateral cortex of calcaneus (E), keeping the calcaneofibular and talocalcaneal ligaments intact (white arrow in F).

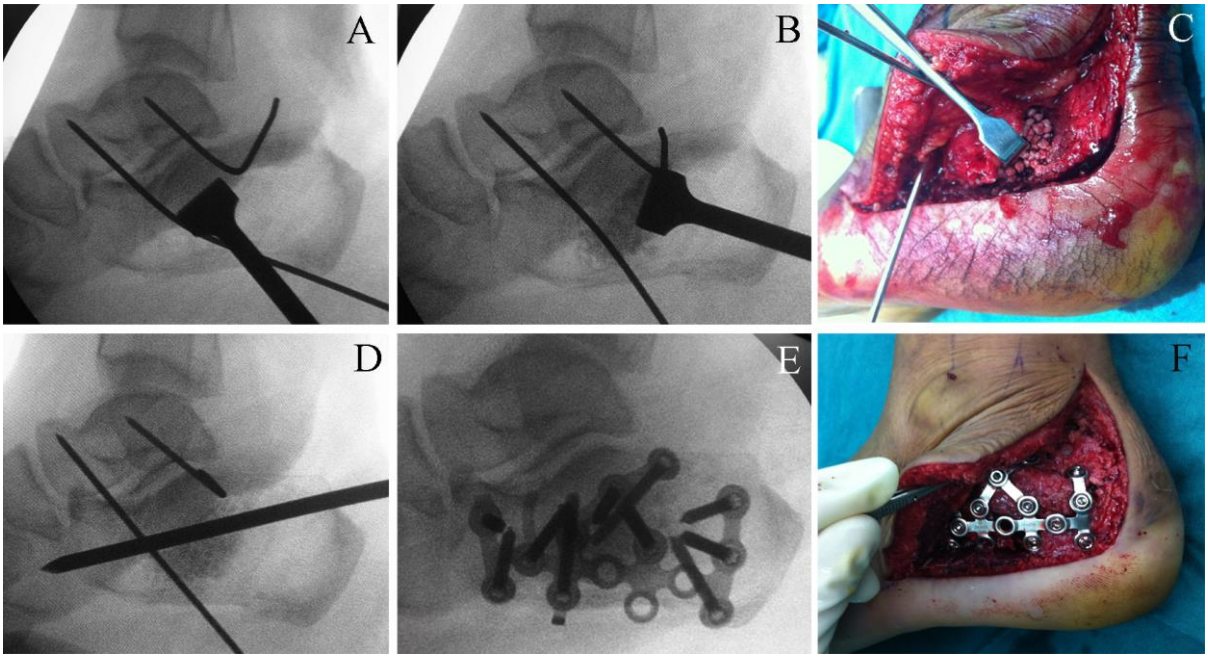

Fig. 2 Impaction technique under fluoroscope using a bone impactor was applied for the reduction of the posterior facet and intra-articular fragments, following by restoration of the Gissane angle, and correction of the articular stepping (A). Hydroxyapatite was filled in the bony defect of the subchondral area for supporting of the reduced fragments (B, C). Percutaneous posterior pinning was used to correct the Bohler angle and varus malalignment (D). An anatomical lateral locking calcaneal plate was applied and fixed (E, F).

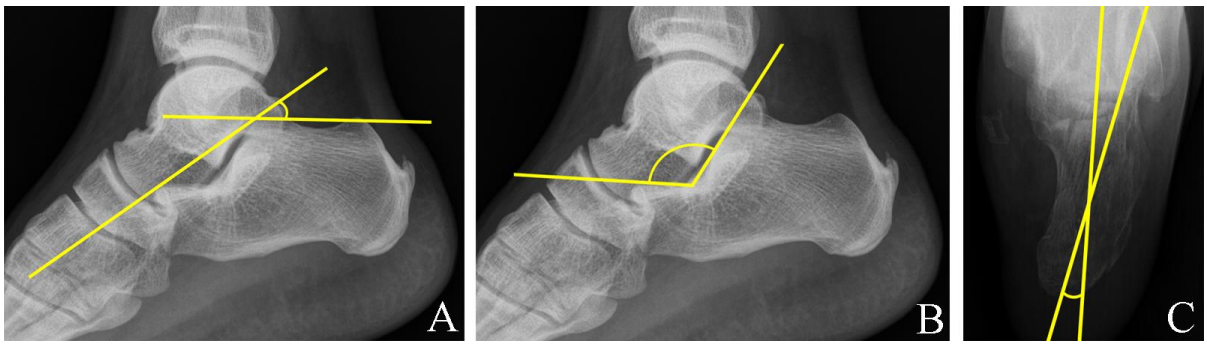

Fig. 3 Radiographic parameters were measured pre- and post-operatively. Bohler and Gissane angles were presented in lateral radiograph (A, B). An axial radiographic measurement of the calcaneal varus angle was made (C).

Results

All 27 calcaneal fractures were assessed, in which no patient met the exclusion criteria. Their demographic data is shown in Table 1. The patients' ages ranged from 27-57 years, with a mean age of 43.1 years. Twenty one patients (77.8%) were male. Calcaneal fractures were categorized as Sanders type III in 22 patients (81.5%), and Sanders type IV in five patients (18.5%). Mean of operative day after injury was 14.8 days, ranging from 10-18 days.

The radiographic parameter results of the operative treatment were compared pre- and post-operatively as shown in Table 2. The impacted reduction technique post-operatively restored the Bohler and Gissane angles from 8.2 (±17.3) to 27.2 (±4.8) degrees, with a mean difference of 19.0 (±17.2) degrees; and 99.2 (±14.4) to 126.7 (±7.1) degrees, with a mean difference of 27.6 (±14.1) degrees, respectively; with a statistically significant difference ($P < 0.001$). This technique also post-operatively reduced the varus angle and articular stepping from 7.3 (±3.6) to 4.4 (±1.1) degrees, with a mean difference of -3.0 (±3.2) degrees); and 4.3 (±0.9) to 0.7 (±0.7) millimeters, with a mean difference of -3.5 (±1.1) millimeters, respectively; with a statistically significant difference ($P<0.001$). Mean of estimated blood loss, operative times, and union times were 78.7 milliliters, 99.2 minutes, and 3.5 months, respectively. There was no significant complication within this technique.

Table 1 Baseline characteristics of the eligible patients.

Characteristics	
Age [mean years, (age range)]	43.1 (27-57)
Male gender [n, (%)]	21 (77.8)
Type of fracture	
- Sanders type III [n, (%)]	22 (81.5)
- Sanders type IV [n, (%)]	5 (18.5)
Operative day [mean days, (day range)]	14.8 (10-18)

Table 2 Pre-operative and post-operative radiographic parameters.

Radiographic parameters	**Pre-operative**	**Post-operative**	**Mean difference ± SD**	**(*P*-value)**
Bohler angle [mean degrees,(±SD)]	8.2 (±17.3)	27.2 (±4.8)	19.0 (±17.2)	< 0.001
Gissane angle [mean degrees, (±SD)]	99.2 (±14.4)	126.7 (±7.1)	27.6 (±14.1)	< 0.001
Varus angle [mean degrees, (±SD)]	7.3 (±3.6)	4.4 (±1.1)	- 3.0 (±3.2)	< 0.001
Articular stepping [mean millimeters, (±SD)]	4.3 (±0.9)	0.7 (±0.7)	-3.5 (±1.1)	< 0.001

Discussion

In this retrospective case series study, the impacted reduction technique provided satisfactory outcomes for Sanders types III and IV of calcaneal fractures. The post-operative radiographic parameters (Bohler angle, Gissane angle, varus malalignment, and articular stepping) were well restored under this technique. Pre- and post-operative comparisons showed the statistically significant difference of each mean difference.

The main advantage of this technique is the preservation of calcaneofibular and talocalcaneal ligaments. This method reduces the extensive dissection of the lateral surgical approach, which is commonly used in lateral plating of calcaneal fractures. However, the study was unable to associate the effects of this less invasive approach directly to the clinical results. Wang, et al., 2016; studied 42 patients with calcaneal fractures, and the effects of ligamentous dissections in the calcaneal fracture fixation[15]. This study found no negative effect on ankle stability after resection of the calcaneofibular ligament in the calcaneal fixation procedure. This study also made no mention of the effect of the resection of both the calcaneofibular and talocalcaneal ligaments through conventional method. Earlier reports of the biomechanical study and the anatomical significance of these ligaments found the calcaneofibular ligament to be the main restraint of the inversed ankle, and the talocalcaneal ligament to be the most significant stabilizer of the subtalar joint[10-13]. These results imply some clinical benefit of the reduction technique with ligamentous sparing in the present study. Therefore, further study of the direct clinical result after ligamentous dissection is still required.

Vittore, et al., 2014; introduced an indirect reduction technique for calcaneal fracture Sanders type II-IV with balloon-assisted reduction under a fluoroscope. Because this technique did not require opening the joint space, intra-articular fractures were reduced indirectly, and were augmented with tricalcium phosphate. Their technique demonstrated favorable clinical results, and restored the Bohler angle for radiographic results, which were similar to the present study[16]. Similar radiographic parameters were also reported as the primary outcome in various studies, which presented similar outcomes. Cottom, et al., 2016; reported that the Bohler and Gissane angles could be restored post-operatively under a simple reduction technique[17]. Gusic et, al., 2015; studied 103 patients with calcaneal fractures, treated with three different operative treatments[18]. Their anatomical and functional outcomes showed satisfactory results in all techniques, similar to the present study.

A disadvantage of this technique is the greater exposure to radiation during the intra-operative fluoroscopic examination. Unexposed articular reduction is a limitation for the removal of incarcerated or loose fragments in the joint space. Nevertheless, some studies were able to demonstrate satisfactory outcomes of operative treatments without exposing the joint space. Cao, et al., 2015; investigated 33 calcaneal fractures, treated by minimally invasive locking plate fixation, without exposing the joint space[18]. Though providing satisfactory clinical outcomes, their technique concerned only Sanders type II and III calcaneal fractures. Percutaneous reduction techniques for calcaneal fractures, which did not

require the exposure of the articular surface, were also widely used and demonstrated satisfactory outcomes[17,19-21].

Limitation

This retrospective study had some limitations, the most of outcomes presented radiographic parameters which could not clearly demonstrate their functional outcomes, despite the reported correlations between radiographic parameters and functional outcomes[4,5]. The measurement bias might be occurred during data collection process of this study, due to the high opportunity of incorrect measurement in severe comminuted fracture types. Intra- and inter-observer reliabilities were also not considered in this study, which may deserve future prospective and comparative study.

Conclusion

The impacted reduction technique for lateral plating in calcaneal fractures, Sanders types III-IV, significantly improved post-operative radiographic parameters including Bohler angle, Gissane angle, varus malalignment, and articular stepping.

Potential conflict of interest

The author declares that there is no conflict of interest.

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ผลการรักษาการจัดเรียงกระดูกส้นเท้าชนิดแตกเข้าข้อโดยเทคนิคอัดแน่นและสงวนเส้นเอ็น

วันจักร พงษ์สมัครไทย, พบ

วัตถุประสงค์: *เพื่อศึกษาผลการรักษากระดูกส้นเท้าหักชนิดแตกเข้าข้อ (Sanders ชนิด III และ IV) ด้วยการเรียงกระดูกแบบอัดแน่น*

วิธีการศึกษา: *ศึกษาทบทวนข้อมูลย้อนหลังจากระบบเวชระเบียนและผลการตรวจภาพถ่ายทางรังสีวินิจฉัยในผู้ป่วยที่มีภาวะกระดูกส้นเท้าหักชนิดแตกเข้าข้อ (Sanders ชนิด III และ IV) ที่มีอายุเท่ากับหรือมากกว่า 18 ปีและได้รับการรักษาโดยการผ่าตัดเรียงกระดูกแบบอัดแน่นและยึดดามโลหะภายในระหว่างเดือนมกราคม 2555 ถึง ธันวาคม 2559 ณ โรงพยาบาลขอนแก่น โดยการเก็บรวบรวมข้อมูลพื้นฐานของผู้ป่วย ค่าที่วัดได้จากภาพถ่ายทางรังสีวินิจฉัย ปริมาณเลือดที่เสีย ระยะเวลาผ่าตัด และระยะเวลาที่กระดูกติด เพื่อนำมาคำนวณค่าทางสถิติ*

ผลการศึกษา: *ผู้ป่วยจำนวนทั้งหมด 27 รายได้เข้ารับการผ่าตัดจัดเรียงกระดูกแบบอัดแน่นและยึดดามโลหะภายใน โดยมีจำนวน 22 ราย (81.5%) เป็นชนิด Sanders III และระยะเวลารอคอยเฉลี่ย 14.8 วัน (พิสัย 10-18 วัน) วิธีดังกล่าวสามารถแก้ไขค่าจากภาพถ่ายทางรังสีวินิจฉัยได้อย่างมีนัยสำคัญเมื่อเทียบกับค่าก่อนผ่าตัด โดยสามารถแก้ไขค่ามุม Bohler จาก 8.2 ± 17.3 เป็น 27.2 ± 4.8 องศา (mean difference 19.0 ± 17.2 องศา), มุม Gissane angle จาก 99.2 ± 14.4 เป็น 126.7 ± 7.1 องศา (mean difference 27.6 ± 14.1 องศา), มุม varus จาก 7.3 ± 3.6 เป็น 4.4 ± 1.1 องศา (mean difference -3.0 ± 3.2 องศา) และ articular stepping จาก 4.3 ± 0.9 เป็น 0.7 ± 0.7 มิลลิเมตร (mean difference -3.5 ± 1.1 มิลลิเมตร) โดยมีความแตกต่างอย่างมีนัยสำคัญทางสถิติ (P < 0.001) ปริมาณการเสียเลือดเฉลี่ยเท่ากับ 78.7 มิลลิลิตร ระยะเวลาในการผ่าตัดเฉลี่ยเท่ากับ 99.2 นาที ระยะเวลาในการติดของกระดูกเฉลี่ยเท่ากับ 3.5 เดือน*

สรุป: *การจัดเรียงกระดูกส้นเท้าหักชนิดแตกเข้าข้อ Sanders ชนิด III และ IV โดยวิธีอัดแน่นสามารถแก้ไขค่ามุม Bohler, มุม Gissane, มุม varus และ articular stepping จากภาพถ่ายทางรังสีวินิจฉัยได้อย่างมีประสิทธิภาพ*