Coronal Plane Small-Fragment Fixation in Supracondylar Intercondylar Femur Fractures

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Abstract

Supracondylar intercondylar distal femur fractures are devastating injuries that frequently have a concurrent coronal plane fracture, which mandates dedicated operative fixation. The purpose of this study was to determine whether small-fragment cortical lag screws oriented in the sagittal plane were sufficient to stabilize coronal plane fractures associated with supracondylar intercondylar distal femur fractures. The authors evaluated short-term radiographic outcomes in 56 coronal plane fractures in 44 knees (27 [61.4%] male, 17 [38.6%] female; mean age, 43 years [range, 19-97 years]) sustaining a supracondylar intercondylar distal femur fracture between January 2001 and November 2013. Coronal plane fractures were stabilized with sagittally oriented small-fragment cortical lag screws measuring 3.5 mm or smaller, and the supracondylar intercondylar component was stabilized with a lateral periarticular plate. Fracture displacement was defined as greater than 2 mm of gapping/translocation of the coronal plane fragment on any radiographic view. Thirty-three (75.0%) knees had open injuries. Fifty-five (98.2%) of 56 coronal plane fractures went on to radiographic union with no displacement of the coronal fragment; one knee developed avascular necrosis and required arthrodesis. Fifteen (34.1%) of 44 knees required secondary procedures unrelated to the coronal plane fracture. The reduction of coronal plane fractures associated with supracondylar intercondylar distal femur fractures can be reliably maintained when stabilized with small-fragment cortical lag screws oriented in the sagittal plane. [Orthopedics. 2016; 39(1):e134-e139]

Coronal plane fractures of the distal femoral condyles rarely occur in isolation but are present in up to 38% of high-energy supracondylar intercondylar (SC-IC) distal femur fractures. Although the lateral femoral condyle is affected most frequently,2,3 medial condyle or bicondylar patterns are observed as well.1 Operative reduction and stabilization of the coronal plane fracture is necessary to avoid further displacement and/or malunion,2,3 minimize postramtic arthritis,3 and optimize the functional result. However, there is no consensus on the optimal form of stabilization that allows maintenance of reduction while minimizing interference with the fixation of the SC-IC fracture. Frequently, large-diameter screws (4.5 or 6.5 mm) are used.5-7 These larger implants can complicate fixation of the SC-IC fragments and require additional cartilage removal during countersinking and may lead to impingement at the patellofemoral joint during knee motion.

Fixation of isolated coronal plane fractures of the distal femoral condyles (known as Hoffa fractures) with small-fragment constructs has previously been reported.8,9 However, previous studies have not reported outcomes of small-fragment fixation of coronal plane frac-
tures associated with complex SC-IC fractures of the distal femur. The purpose of this study is to report short-term radiographic outcomes for coronal plane fractures associated with SC-IC distal femur fractures. The authors hypothesized that small-fragment cortical lag screws oriented in the sagittal plane would reliably maintain reduction of coronal plane fractures associated with SC-IC distal femur fractures.

**Materials and Methods**

**Patient Population**

Internal review board approval was obtained prior to the initiation of this study. All patients who underwent surgical management of an intra-articular fracture of the distal part of the femur between January 2001 and November 2013 were identified through a search of a prospectively collected single-hospital orthopedic database. Exclusion criteria included patients who were skeletally immature, patients who did not survive the perioperative period, and patients lost to follow-up prior to 6 months (Figure 1). Also excluded from the final analysis were patients with coronal plane fractures stabilized with any fixation construct other than small-fragment cortical lag screws (although these patients were analyzed separately to determine whether there were particular features that necessitated a change in the fixation strategy). The fractures were classified according to the Orthopaedic Trauma Association (OTA) and AO criteria,10,11 and open injuries were classified using the criteria of Gustilo and Anderson.12,13 All patients received their definitive surgical procedure at the authors’ institution, a single Level I orthopedic trauma center. Over the study period, a total of 126 AO/OTA type 33-C3 knees were identified, 77 of which had an associated coronal plane fracture.

**Surgical Management**

The patient is placed supine on a radiolucent table. A sterile tourniquet may be used. The surgical approach is typically dependent on the condylar involvement of the distal femur. For fixation of the supracondylar and intercondylar portions of the fracture, either a direct lateral or a lateral parapatellar approach is used; lateral coronal plane fractures can be accessed through either approach, and visualization is aided by 20° of knee flexion. For medial coronal plane fractures, a lateral parapatellar or supplementary medial subvastus approach is used in combination with a direct lateral approach. The lateral parapatellar approach is preferred because medial patellar subluxation allows simultaneous access to the intercondylar fracture and the medial coronal plane fracture.14

For fracture reduction, a pointed reduction clamp is placed in the anteroposterior plane to compress the fracture. Soft tissues typically prevent direct visualization of the posterior exit point of the coronal plane fracture; therefore, the accuracy...
of the reduction is judged by assessing the continuity of the articular surface on biplanar fluoroscopy combined with direct visualization of the articular reduction anteriorly. The major fragments are temporarily fixed with Kirschner wires (Figure 2), followed by definitive fixation of the coronal plane fracture with small-fragment cortical lag screws (2.4, 2.7, or 3.5 mm) placed from anterior to posterior, perpendicular to the major coronal plane fracture. Implants placed through the articular surface are countersunk below the cartilage surface. The articular block is then reduced to the metadiaphyseal segment, and the supracondylar intracondylar distal femur fracture is stabilized using a lateral locked plate or other fixed-angle implant. The small diameter of the sagittal plane screws minimizes the interference with the larger screws securing the lateral plate (Figure 3).

The knee is manually ranged to assess overall knee stability and femorotibial gliding, and the overall construct and accuracy of the reduction are confirmed radiographically.

**Rehabilitation**

The typical rehabilitation protocol includes nonweight bearing on the operative extremity with range of motion as tolerated and immediate out-of-bed mobilization with physical therapy. At 12 weeks, the patient is allowed to begin weight bearing if plain radiographs demonstrate appropriate fracture healing.

**Database Review**

All pre- and postoperative patient records, operative notes, plain radiographs, and computed tomography (CT) scans were retrospectively reviewed by a single reviewer (J.J.M.T.) for internal consistency. Coronal plane fractures were identified by careful assessment of plane radiograph orthogonal views and CT scans when available. All imaging was critically evaluated for coronal plane fracture displacement, implant failure, or other changes that occurred between the immediate postoperative radiographs and those taken at latest follow-up. Fracture displacement was defined as greater than 2 mm of gapping or translation of the coronal plane fracture on any radiographic view. Construct failure was defined as any change in implant position that caused greater than 2 mm displacement of the coronal plane fracture. Union of the coronal plane fracture was determined by the absence of fracture displacement or implant failure at 6 months postoperatively.

**Statistical Analysis**

Study data were collected and managed using the Research Electronic Data Capture (REDCap) tool (Vanderbilt University, Nashville, Tennessee). Statistical analysis including means, ranges, SDs, and percentiles were performed using Microsoft Excel (Microsoft Corporation, Redmond, Washington).
RESULTS

Study Population

Of the 77 knees with AO/OTA type 33-C3 fractures and associated coronal plane fractures, 5 patients (5 knees) died in the immediate postinjury period (Figure 1). Due to severe crush or blast injuries, 10 knees required either above-knee amputations (n=6), arthrodesis (n=1), or oncologic total knee arthroplasty (n=3). The remaining 62 knees underwent open reduction and internal fixation of a coronal plane fracture as well as the associated SC-IC fracture. Five knees were excluded because fixation consisted of a small-fragment plate (n=1), combined small-fragment plate and sagittal plane screws (n=3), or a single cannulated 4.0-mm screw (n=1). Compared with the included cohort, these 5 patients showed no differences in demographic factors or injury patterns, and the choice of fixation was due to the preference of the treating surgeon. An additional 13 knees were lost to follow-up prior to 6 months and were therefore excluded; these patients also showed no differences in demographic factors or injury patterns.

The final study population of 56 coronal plane fractures in 44 knees (44 patients) included 27 (61.4%) males and 17 (38.6%) females with a mean age of 43 years (range, 19-97 years); there were no cases of bilateral knee injuries. All coronal plane fractures were stabilized with small cortical lag screws measuring 3.5 mm in diameter or smaller. Thirty-three small cortical lag screws measuring 3.5 mm in diameter or smaller were placed into each coronal plane fracture in 44 knees (44 patients) included 27 (61.4%) males and 17 (38.6%) females with a mean age of 43 years (range, 19-97 years); there were no cases of bilateral knee injuries. All coronal plane fractures were stabilized with small cortical lag screws measuring 3.5 mm in diameter or smaller.

Coronal Plane Fracture Fixation

The coronal plane fracture involved only the lateral condyle in 20 (45.5%) knees, only the medial condyle in 12 (27.3%) knees, and both condyles in 12 (27.3%) knees; there were a total of 24 medial and 32 lateral coronal plane fractures. Seventy-seven percent of knees underwent provisional external-fixator placement, and definitive operative stabilization was performed an average of 6.5±5.1 days following the initial injury. The most common (39.3%) fixation construct consisted of two 3.5-mm cortical screws. An average of 2 small-fragment fully threaded cortical screws were placed into each coronal plane fracture in standard lag fashion (Table 1).

Follow-up

Average follow-up was 24.5 months (range, 6-107 months) in this population of patients with a minimum of 6 months of follow-up. Fifteen (34.1%) of 44 knees returned to the operating room for secondary procedures, largely unrelated to the fixation of the coronal plane fracture (Table 2) and most commonly for repair of a supracondylar nonunion or planned staged bone grafting. Fifty-five (98.2%) of 56 coronal plane fractures progressed to radiographic union with no displacement of the coronal fragment. One knee developed a supracondylar nonunion and eventual avascular necrosis of the distal lateral femoral condyle, including the coronal plane fragment. This knee was converted to an arthrodesis 1.5 years after the initial injury and represents the only failure of coronal plane fracture small-fragment fixation in this cohort.

DISCUSSION

Isolated coronal plane fractures of the distal femoral condyle occur infrequently and were originally described by Hoffa in 1904. With the advent of modern advanced imaging techniques, it is now known that coronal plane fractures are associated in up to 38% of SC-IC distal femur fractures, thus further complicating these already complex injuries. It is generally agreed that operative stabilization of the coronal plane fragment, whether

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Table 1

<table>
<thead>
<tr>
<th>Screw Diameter, mm</th>
<th>No. of Screws</th>
<th>No. (%) of Condyles (N=56)</th>
</tr>
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<tbody>
<tr>
<td>2.4</td>
<td>1</td>
<td>1 (1.9)</td>
</tr>
<tr>
<td>2.4</td>
<td>2</td>
<td>10 (17.9)</td>
</tr>
<tr>
<td>2.4</td>
<td>3</td>
<td>2 (3.6)</td>
</tr>
<tr>
<td>2.7</td>
<td>1</td>
<td>4 (7.1)</td>
</tr>
<tr>
<td>2.7</td>
<td>2</td>
<td>3 (5.4)</td>
</tr>
<tr>
<td>2.7</td>
<td>3</td>
<td>4 (7.1)</td>
</tr>
<tr>
<td>3.5</td>
<td>1</td>
<td>6 (10.7)</td>
</tr>
<tr>
<td>3.5</td>
<td>2</td>
<td>22 (39.3)</td>
</tr>
<tr>
<td>3.5</td>
<td>3</td>
<td>4 (7.1)</td>
</tr>
</tbody>
</table>

*Size and number of small-fragment cortical lag screws placed into coronal plane fractures associated with supracondylar intracondylar distal femur fractures. There were 56 coronal plane fractures in 44 knees.*

Table 2

<table>
<thead>
<tr>
<th>Secondary Surgery Indication</th>
<th>No. (%) of Knees (N=44)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair of supracondylar nonunion</td>
<td>9 (20.5)</td>
</tr>
<tr>
<td>Staged bone grafting of metadiaphyseal defect</td>
<td>6 (13.6)</td>
</tr>
<tr>
<td>I &amp; D for infection</td>
<td>4 (9.1)</td>
</tr>
<tr>
<td>Manipulation under anesthesia</td>
<td>4 (9.1)</td>
</tr>
<tr>
<td>Symptomatic HO excision</td>
<td>2 (4.5)</td>
</tr>
<tr>
<td>Delayed flap coverage</td>
<td>1 (2.3)</td>
</tr>
<tr>
<td>Arthrodesis</td>
<td>1 (2.3)</td>
</tr>
</tbody>
</table>

Abbreviations: HO, heterotrophic ossification; I & D, irrigation and debridement.

*Indications for secondary procedures following operative fixation of supracondylar intracondylar distal femur fractures with associated coronal plane fractures. Fifteen of 44 knees required one or more secondary procedures following initial operative fixation; most knees had multiple indications for surgery. All infected knees required multiple debridements.*
in isolation or when associated with a comminuted distal femur fracture, is required for an acceptable functional outcome. Internal fixation allows for stable reconstruction of the articular surface and permits early range of motion. However, prior investigations are limited and do not focus on the implant size necessary to maintain reduction in coronal plane fractures associated with SC-IC fractures of the distal femur.

There is no consensus on the optimal form of coronal plane fracture stabilization that allows maintenance of reduction while minimizing interference with the fixation of the SC-IC fracture. Various studies have used large-diameter screws or small plates. These larger implants can complicate fixation of the SC-IC fragments, require additional cartilage removal during countersinking, and impinge during knee range of motion if not placed properly. Furthermore, lateral fixed-angle devices with standard locking screws likely do not provide adequate fixation for coronal plane fractures. Standard locking screw trajectories are defined by the implant design and cannot be adjusted for comminution in the coronal plane; and even if fragment engagement by the screws is possible, compression cannot be obtained. Variable-angle locking plates may allow for enhanced fixation of coronal plane fractures due to strategic screw trajectories, but compression perpendicular to the coronal plane fracture is still not possible with these implants. Small fragment screws avoid many of these issues and have the added advantage of maximizing the screw corridors for lateral fixed-angle implants (Figure 3), thus causing less interference with fixation of the SC-IC fracture. Furthermore, these screws can more precisely target smaller fracture fragments, potentially allowing for fixation of comminuted components not feasible with larger screws and placement of more screws into each fragment.

In isolated coronal plane fractures of the distal femur (Hoffa fractures), several studies have demonstrated good results using 2.4-mm cortical screws, 3.5-mm cortical screws, or 4.0-mm cancellous screws. Similarly, the findings of the current study indicate that small-fragment screws oriented in the sagittal plane were able to maintain reduction at follow-up, even when associated with complex distal femur fractures. Furthermore, in the current series, despite 1 in 5 knees (9 [20.5%] of 44 knees) developing a supracondylar nonunion, the rate of successful fixation and subsequent union of the coronal plane fragment was 98.2% (55 of 56 condyles).

Biomechanically, the use of small-diameter screws has few disadvantages. The stiffness of one or two 3.5-mm screws is equivalent to that achieved with a single 6.5-mm screw in a sawbones model of coronal plane fractures, and the required load to displace the fracture was comparable between two 3.5-mm screws and a single 6.5-mm screw. Although the current authors did not seek to test the biomechanical properties of their fixation construct, they noted no radiographically apparent displacement after patients resumed full weight bearing, even when using smaller implants.

It has been previously reported that two 6.5-mm screws placed posteroanteriorly (PA) had less displacement than 2 anteroposteriorly (AP) placed screws (P = 0.05) in a coronal plane fracture model. Although statistically significant, given that the displacement averaged only 1.36 mm in the AP group compared with 0.67 mm in the PA group, it is unknown what clinical effect this small difference in displacement would have. From a practical standpoint, placement of screws from posterior to anterior is often difficult or impossible in the injured extremity. In addition, with knee flexion the posteriorly located screw heads would be countersunk in the weight-bearing portion of the distal femoral condyle. Although the current study did not aim to evaluate screw orientation, the screw trajectory that achieves the strongest and most accurate fixation with the least amount of stripping to the already traumatized fragments is preferable.

The high reoperation rate in this series (34.1%), which included staged bone grafting, emphasizes the complex nature of these injuries. In the current study, which included only highly comminuted 33-C3 patterns, 75% were open fractures. This population is frequently polytraumatized as a result of high-energy injuries (mean Injury Severity Score, 21.5). Management of these patients usually requires a concerted effort between multiple surgical and intensivist services, and emergent treatment of other nonorthopedic injuries and/or clinical instability may delay definitive fixation. Open wounds, vascular injury, traumatized soft tissue, massive comminution, segmental bone loss, and gross contamination can all potentially complicate fixation. The orthopedist must anticipate the high complication rate associated with these injuries and have a low threshold to perform secondary procedures as needed.

The primary outcome measure of this study was maintenance of reduction based on analysis of radiographs. Functional outcomes are desirable but were not obtained. An excellent radiographic result does not necessarily correlate with the patient’s functional status, nor does it guarantee patient satisfaction. Furthermore, given the severity of these injuries, it may be difficult to discern what contribution small changes in coronal fragment alignment have on the overall morbidity of the trauma. During the early phases of this study, CT scans were not routinely obtained, and some coronal plane fractures potentially could have been missed because they are sometimes difficult to see on plain radiographs, especially in highly comminuted patterns. Furthermore, in some instances the locking screws from the lateral plate may have passed into the coronal plane fragment. Although these screws are not orthog-
nal to the fracture and do not provide any compressive strength, they potentially contributed a small degree of supplemental stability; however, in the absence of routine postoperative CT scans, this relationship could not be accurately explored. An additional limitation of this study is its retrospective nature; it is therefore subject to information, selection, and attrition bias. Finally, as a tertiary referral center covering a large geographic area, follow-up is predictably diminished because patients are ultimately discharged back to their homes, which are frequently hundreds of miles away from the authors’ trauma center. However, all patients in this study had a minimum of 6 months of follow-up, and radiographs were taken after the patients had resumed full weight bearing. In the opinion of the authors, if the construct had not failed at the 6-month mark, after the patients had been fully weight bearing and stressing their constructs, it was unlikely to do so in the future. Similarly, avascular necrosis and resorption are identifiable by this stage.

**Conclusion**

The reduction of coronal plane fractures associated with SC-IC distal femur fractures can be reliably maintained when stabilized with small-fragment cortical lag screws oriented in the sagittal plane. The use of larger screws and implants for coronal plane fracture stabilization may complicate fixation of the SC-IC components of the fracture and may not be necessary.

**References**