Accuracy of Distal Femoral Valgus Deformity Correction: Fixator-Assisted Nailing vs Fixator-Assisted Locked Plating

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Authors:
Florian M. Kovar, MD Julio J. Jauregui, MD John E. Herzenberg, MD

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Dr. Kovar is an Orthopaedic Surgeon, Landesklinikum Baden-Mödling, Austria. Dr. Jauregui is an Orthopedic Surgery Resident, University of Maryland, Department of Orthopedics, Baltimore, Maryland. Dr. Herzenberg is Head of Pediatric Orthopedics, Sinai Hospital, and Director of the International Center for Limb Lengthening, Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore, Baltimore, Maryland.

Address correspondence to: John E. Herzenberg, MD, Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore, 2401 W. Belvedere Avenue, Baltimore, MD 21215 (tel, 410-601-9562; fax, 410-601-9575; email, jherzenberg@lifebridgehealth.org).

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Take-Home Points

- FAN and FALP are methods to improve the accuracy of long bone deformity correction.
- Both methods include temporary stabilization of the osteotomy with an external fixator.
- FALP is technically easier, since the external fixation pins do not have to be positioned out of the path of the nail, as in FAN.
- Acute corrections in the distal femur from valgus to varus can stretch the peroneal nerve.
- FAN and FALP are equivalent techniques for improving accuracy of deformity correction.

Multiple etiologies for distal femoral valgus deformity have been described in the literature. These can be congenital, developmental, secondary to lateral compartmental arthritis, or posttraumatic. If not corrected,
Femoral deformities alter the axial alignment and orientation of the joints, and may lead to early degenerative joint disease and abnormal leg kinematics. After correcting these deformities, the goal of treatment is to obtain anatomic distal femoral angles and neutral mechanical axis deviation (MAD), but without overcorrecting into varus. Numerous techniques to fix these deformities, such as progressive correction with external fixation or acute correction open reduction with internal fixation (ORIF), have been described. Modern external fixation allows for a gradual, adjustable, and more accurate correction but may produce discomfort and complications for patients. In contrast, ORIF may be more tolerable for the patient, but to achieve a precise correction, considerable technical skills and expertise are required.

Two techniques used to correct these valgus femoral deformities in adults are fixator-assisted nailing (FAN) and fixator-assisted locked plating (FALP). FAN and FALP combine the advantage of external fixation (accuracy, adjustability) with the benefits of internal fixation (patient comfort), because the osteotomy and correction are performed with the guidance of a temporary external fixator and then permanently fixated by an intramedullary (IM) nail or a locking plate. Both techniques have the possibility to correct varus and valgus deformities, but whenever correcting sagittal plane angulation, the FAN technique may be more challenging. The paucity of studies available involving FAN and FALP do not lead to a conclusive preference of one technique over the other relative to the accuracy and success of correction.

In both FAN and FALP, the external fixator is applied and adjusted after the osteotomy for accurate alignment. In FALP, the plate is added without moving the leg from its straight position. However, in FAN, the knee must be flexed to 30° to 90° for insertion of the retrograde knee nail, and the alignment may be lost if the external fixation is not fully stable. Therefore, we hypothesized that FAN would be less accurate than FALP. Hence, the purposes of this study is to compare the correction achieved with FAN and FALP in patients with distal femoral valgus deformities and to describe the intraoperative complications associated with both techniques.

**Materials and Methods**

After proper Institutional Review Board approval was obtained, a consecutive cohort of 35 patients who underwent femoral deformity correction with either FAN or FALP during an 8-year period (January 2002 to December 2010) was retrospectively reviewed. Eleven patients had to be excluded because of inadequate follow-up (<12 months) or because additional procedures were simultaneously performed. A total of 24 patients (27 femora) who had a mean age of 26 years (range, 14-68 years) were included in the final study cohort. Specifically, 20 femora (18 patients) were corrected using the FAN technique (7 males and 11 females; mean age, 36 years; range, 14-68 years), and 7 femora (6 patients) were fixed using the FALP technique (2 males and 4 females; mean age, 16 years; range, 15-19 years). The median follow-up in the FAN cohort was 5 years (range, 1-10 years), and the median follow-up in the FALP cohort was 5 years (range, 1-8 years) (Table 1).

The specific measurements performed in all patients were MAD, mechanical lateral distal femoral angle (mLDFA), and medial proximal tibia angle (MPTA). These were measured from standing anteroposterior radiographs of the knee that included the femur. All outcome data were collected from the medical charts, operative reports, and radiographic evaluations. To ensure accuracy, all measurements were performed by 2 authors blinded to each other’s measurements. If a variation of <5% was obtained, the results were averaged and used for further analysis. Whenever a difference of >5% was obtained, the measurement was repeated by both authors for confirmation.
Surgical FAN Technique

After measuring the deformity (Figure 1A) with the patient under general anesthesia on a radiolucent table, the involved lower limb is prepared and draped. Two half-pins are inserted medially, 1 proximal and 1 distal to the planned osteotomy site (Figure 1B), and then connected loosely with a monolateral external fixator. Special care is taken while placing the half-pins, not to interfere with the insertion path of the IM rod. When performing the preoperative planning, the level of osteotomy is chosen to enable the placement of at least 2 interlocking screws distal to the osteotomy. Then, a percutaneous osteotomy is performed from a lateral approach, and the bone ends are manipulated (translation and then angulation) to achieve the desired deformity correction. The external fixator is then stabilized and locked in the exact position (Figure 1C). Subsequently, retrograde reaming, nail insertion, and placement of proximal and distal locking screws are performed (Figure 1D). Blocking screws may give additional stability. The removal of the external fixator is the final step (Figure 1E).  

When using the FAN technique, special attention is paid to reducing the risk of fat embolism. This can be reduced but not totally eradicated with the use of reaming irrigation devices. In our technique of FAN, the bone is cut and displaced prior to reaming so that the pressure of reaming is vented out through the osteotomy, along with the reaming contents, which theoretically can then act as a "prepositioned bone graft" that may speed healing.

Surgical FALP Technique

Preoperatively, a decision concerning the planned osteotomy and the correct locking plate size is made. In addition, the outline of the plate is marked on the skin. Under general anesthesia, the patients are prepared and draped. A tourniquet is elevated around the upper thigh. Then, 2 half-pins are medially inserted, 1 proximal and 1 distal to the planned osteotomy site, and are then connected loosely with a monolateral external fixator (Figure 2A). A lateral approach to the distal femur is done, preserving the periosteum, except at the level of the osteotomy. After the osteotomy is performed (through an open lateral incision), both segments are translated (Figure 2B) and then the distal segment is angulated to achieve the desired deformity correction, and the desired position is then stabilized by tightening the external fixator connectors (Figure 2C). Subsequently, a locking plate is inserted in the submuscular-extraperiostal plane. The plate does not require being in full contact (flush) with the bone. At least 3 screws are placed on both sides of the osteotomy through a long lateral incision (Figure 2D). Bone graft may be added to the osteotomy site to encourage healing. Then, the external fixator is removed, and all incisions are closed (Figure 2E).  

During each of the procedures, we aimed at having "perfect alignment" with a MAD of 0 mm, in which a Bovie cord is used and passed through the center of the femoral head, knee, and ankle. However, to confirm that the surgery was successful, the actual measurements were performed on standing long-leg films. These films were obtained preoperatively and at latest follow-up. They were performed with the patella aiming forward, the toes straight ahead, feet separated enough for good balance, knees fully extended, and weight equally distributed on the feet. Postoperatively, in both cohorts, partial weight-bearing was encouraged immediately with crutches; physical therapy was instituted daily for knee range of motion. Radiographs were scheduled every 4 weeks to monitor callus formation. Full weight-bearing was allowed when at least 3 cortices were consolidated.  

All statistical analyses were performed with the aid of the SPSS statistical software package (SPSS). Average
values and standard error of the mean were assigned to each variable. A nonparametric Mann-Whitney U test was used, and a 2-tailed $P < .05$ was considered significant. Correlation of continuous variables was determined by Spearman’s correlation coefficient. Also, multivariate Cox regression analyses after adjustment for age, sex, and deformity correction were used to detect associations within the study population. To evaluate whether our data were normally distributed, Shapiro-Wilk tests were performed.

Results

The mL DFA significantly improved in the FAN cohort from a mean of 81° to a mean of 89° (ranges, 67°-86° and 80°-100°; respectively; $P = .001$) (Figures 3A, 3B). Similarly, the mean mL DFA in the FALP cohort also significantly improved, from 80° preoperatively to 90° postoperatively (range, 71°-87° and 88°-94°, respectively; $P < .001$) (Figures 4A, 4B). The mean amounts of correction of mL DFA were 8° (range, 3°-18°) in the FAN group and 10° (range, 7°-17°) in the FALP group (Table 2). After evaluating the MPTA, in the FAN cohort, we found that the mean pre- and postoperative MPTAs were not modified. These patients had a mean preoperative angle of 88° (range, 62°-100°), which was kept postoperatively to a mean of 88° (range, 78°-96°). In the FALP cohort, a slight change from 90° to 88° was observed (ranges, 82°-97° and 83°-94°, respectively). None of these changes in MPTA were significant ($P > .05$).

When evaluating correction of the MAD, we observed that the FAN cohort changed from a preoperative MAD of 32 mm (range, 6-64 mm) to a postoperative mean of 10 mm (range, 0-22 mm), and this correction was statistically significant ($P = .001$). The FALP cohort changed from a mean of 34 mm (range, 17-62 mm) preoperatively to 4 mm (range, 0-11 mm) postoperatively, and this was also statistically significant ($P = .002$). The mean MAD correction for the FAN group vs FALP group was 27 mm vs 32 mm, respectively (Table 2).

In patients with valgus femoral deformity, the MAD is usually lateralized; however, in the FAN cohort, we included 3 patients with medial MADs (10 mm, 13 mm, and 40 mm). This is justified in these patients because a complex deformity of the distal femur and the proximal tibia was present. In the extreme case of a 40-mm medial MAD, the presurgery mL DFA was 76°, and the presurgery MPTA was 62°. The amount of deformity correction in this patient was 16°.

During the follow-up period, 2 complications occurred in the FAN group. One patient developed gait disturbance that resolved with physical therapy. Another had an infection at the osteotomy site. This was addressed with intravenous antibiotic therapy, surgical irrigation and débridement, hardware removal, and antegrade insertion of an antibiotic-coated nail. In the FALP group, 1 patient developed a persistent incomplete peroneal nerve palsy attributed to a 17° correction from valgus to varus, despite prophylactic peroneal nerve decompression. Nonetheless, the patient was satisfied with the result, recovered partial nerve function, and returned for correction of the contralateral leg deformity. When comparing the complications between both cohorts, no significant differences were found: 2 of 18 cases (11%) in the FAN group vs 1 of 6 cases (17%) in the FALP group ($P = .78$).

Discussion

The goal of this study was to compare the accuracy of deformity corrections achieved with either FAN or FALP. A number of authors have described results after deformity correction with several plating and nailing techniques; however, the information derived from comparing these 2 techniques is limited. We hypothesized that FALP would be more accurate, because less mobilization during fixation is required. However, we found no significant
differences between these 2 techniques.

This study has several limitations. First, the small size of our cohort had to be further reduced owing to limited data; nevertheless, this pathology and the treatment methods used are not commonly performed, which make this cohort 1 of the largest of its type described in the literature. Also, the procedures were performed by multiple surgeons in a population with a wide age range, creating multiple additional variables that complicate the comparison of the sole differences between FAN and FALP. However, owing to these variables, the generalizability of this study may be increased, and similar outcomes can potentially be obtained by other institutions/surgeons. In addition, the variability of our follow-up period is another limitation; however, these patients were all assessed until bony union after skeletal maturity was achieved. Hence, the development of additional deformity is not expected. The lack of clinical outcome with a standardized questionnaire may also be seen as a limitation. However, because the purpose of our study was to assess both surgeries in terms of their ability to achieve angular correction, the addition of patient-reported outcomes may have increased the variability of our data.

The foremost objective in valgus deformity correction is to establish joint orientation angles within anatomic range to prevent overloading of the lateral joint and thereby prevent lateral compartmental osteoarthritis. \textsuperscript{2,20,27-29} There are 2 categories of fixation: internal and external. With FAN and FALP, we strive to have the adjustability and accuracy of external fixation with the comfort (for the patient) of internal fixation. Accurate osteotomy correction requires an accurate preoperative analysis and osteotomy close to the apex of the deformity. \textsuperscript{16,21,30-33} The most commonly used osteotomy techniques are drill-hole,\textsuperscript{31} focal dome,\textsuperscript{34} rotation, and open- or closed-wedge osteotomies.\textsuperscript{35,36} After the osteotomy, the resultant correction has to be stabilized. In recent years, the popularity of plates instead of an IM nail for internal fixation has been driven by the rapid development of low contact locking plates.\textsuperscript{16,19,26,30,37-40}

There are certain advantages of using FAN over FALP. In older patients who may require a subsequent total knee arthroplasty (TKA), the midline incision used for retrograde FAN technique is identical to that made for TKA. In contrast, in a younger and more active population, with a longer life expectancy, the extra-articular FALP approach has the advantage of not violating the knee joint. In addition, locking plates may achieve a more rigid fixation than IM nails; however, the stability of IM nails can be augmented with blocking screws.

In 20 patients, including children and young adults, with frontal and sagittal plane deformities, Marangoz and colleagues reported on correction of valgus, varus, and procurvatum deformities using a Taylor Spatial Frame (TSF). Successful correction of severe deformities was achieved gradually with the TSF, resulting in a postoperative deformity (valgus group) of mL DFA 88.9° (range, 85°-95°).\textsuperscript{7} In a more recent study, Bar-On and colleagues\textsuperscript{15} described a series of 11 patients (18 segments) with corrective lower limb osteotomies in which all were corrected to within 2° of the planned range. Similarly, Gugenheim and Brinker\textsuperscript{20} described the use of the FAN technique to correct distal varus and valgus deformities in 14 femora. The final mean mL DFA and MAD in the valgus group were 89° (range, 88°-90°) and 5 mm (range, 0-14 mm medial), respectively.

In their comparative study, Seah and colleagues\textsuperscript{11} described monolateral frame vs FALP deformity correction in a series of 34 extremities (26 patients) that required distal femoral osteotomy. No differences related to knee range of motion or the ability to correct the deformity between internal and external fixation were reported (\(P > .05\)). Similarly, Eidelman and colleagues\textsuperscript{1} evaluated the outcomes of 6 patients (7 procedures) who underwent surgery performed with the FALP technique for distal femoral valgus deformity. They concluded that this technique is minimally invasive and can provide a precise deformity correction with minimal morbidity.
Other methods of fixation while performing FAN have been described by Jasiewicz and colleagues, who evaluated possible differences between the classic Ilizarov device and monolateral fixators in 19 femoral lengthening procedures. The authors concluded that there is no difference between concerning complication rate and treatment time. The use of FAN has also been described in patients with metabolic disease who required deformity correction. In this regard, Kocaoglu and colleagues described the use of a monolateral external fixator in combination with an IM nail in a series of 17 patients with metabolic bone disease. The authors concluded that the use of the IM nail prevented recurrence of deformity and refracture. Kocaoglu and colleagues also published a series of 25 patients treated with the FAN and LON (lengthening over a nail) technique for lengthening and deformity correction. The mean MAD improved from 33.9 mm to 11.3 mm (range, 0-30 mm). In contrast, Erlap and colleagues compared FAN with circular external fixator for bone realignment of the lower extremity for deformities in patients with rickets. Although no significant difference was found between both groups, FAN was shown to be accurate and to provide great comfort to patients, and it also shortened the total treatment time. Finally, the advent of newer technologies could also provide alternatives for correcting valgus deformities. For example, Saragaglia and Chedal-Bornu performed 29 computer-assisted valgus knees osteotomies (27 patients) and reported that the goal hip-knee angle was achieved in 86% of patients and that the goal MPTA was achieved in 100% of patients.

**Conclusion**

Both the FALP and FAN methods of femoral deformity correction are safe and effective surgical techniques. In our opinion, the advantages of the FALP technique result from the easy lateral surgical approach under medial external fixation and stabilization of the osteotomy without bending the knee. Ultimately, the decision to use FAN may be influenced by the surgeon’s perception of the potential need for future TKA. In such cases, a midline anterior approach with nailing is very compatible with subsequent TKA. The surgeon’s experience and preference, while keeping in mind the patient’s predilection, will play an important role in the decision-making process. Larger prospective clinical trials with larger cohorts have to be conducted to confirm our findings.

**Key Info**

**Figures/Tables**

Figures / Tables:

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Figure 1. Fixator assisted nailing for distal right femoral valgus deformity. (A) Apex analysis of the deformity. Blue (distal) line is based on a population average 87° mechanical lateral distal femoral angle (mLDFA) (blue line). Red (proximal) line is the mechanical axis of the proximal femur, with the "3-line" method (7° population anatomic-mechanical axis angle). Magnitude of deformity equals 12°. (B) Proximal and distal fixation pins applied perpendicular to respective segments, and cut of the path of the nail distally. Osteotomy slightly above the apex. Two pins above and below give better stability when the knee is flexed to insert the retrograde. (C) Osteotomy complete. Distal segment rotated to create 87° mLDFA. Note required translation at the osteotomy level, because the osteotomy is above the level of the apex. (D) Fixation holds the osteotomy still, while the retrograde nail is inserted and locked. (E) Once the nail is locked, the external fixator may be removed. A blocking screw in the distal segment lateral to the nail helps to prevent relapse of the valgus.

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Figure 2. Fixator assisted locked plating for distal left femoral valgus deformity. (A) Similar bone deformity as in Figure 1, but here the apex analysis shows a deformity of 10°. External fixator applied. A single pin above and below is sufficiently stable, since the leg is kept extended on the table throughout the case. (B) Osteotomy slightly above the apex, requires translation at the osteotomy. First translate without tension. (C) After the initial translation, the bones are angulated to create a normal (87°) lateral distal femoral angle. Adjust until satisfied with correction, then tighten the clamps. (D) Fixator clamps tightened to hold the osteotomy still, while the lateral locking plate is applied. Bone to plate contact is not required, due to the locking plate technology. (E) Once the plate is locked, the external fixator may be removed. The locking plate functions as an “internal” external fixator. Bone graft may be added to the opening wedge osteotomy to speed healing.

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Figure 3. (A) Preoperative and (B) postoperative full-length radiographs of a patient undergoing deformity correction with the fixator-assisted nailing technique.

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Figure 4. (A) Preoperative and (B) postoperative full-length radiographs of a patient undergoing deformity correction with the fixator-assisted locked plating technique.

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### Table 1. Study Details and Demographic Characteristics

<table>
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<th>Detail</th>
<th>Overall</th>
<th>FAN</th>
<th>FALP</th>
</tr>
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<tbody>
<tr>
<td>Number of patients</td>
<td>24</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>Number of femurs</td>
<td>27</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>Age in years (range)</td>
<td>26 (14 to 68)</td>
<td>36 (14 to 68)</td>
<td>16 (15 to 19)</td>
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<tr>
<td>Male:Female</td>
<td>9:15</td>
<td>7:11</td>
<td>2:4</td>
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<tr>
<td>Median follow-up in years (range)</td>
<td>5 (1 to 10)</td>
<td>5 (1 to 10)</td>
<td>5 (1 to 8)</td>
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</table>

Abbreviations: FALP, fixator assisted locked plating; FAN, fixator assisted nailing

### Table 2. Deformity Correction

<table>
<thead>
<tr>
<th>Measurement</th>
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<th>Preoperative</th>
<th>Postoperative</th>
<th>P Value</th>
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<td>mLDFA in degrees (range)</td>
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<td>81 (67 to 86)</td>
<td>89 (80 to 100)</td>
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<td>FALP</td>
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<td>90 (88 to 94)</td>
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<tr>
<td>Mechanical axis deviation in mm (range)</td>
<td>FAN</td>
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<td>FALP</td>
<td>34 (17 to 62)</td>
<td>4 (0 to 11)</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Abbreviations: FALP, fixator assisted locked plating; FAN, fixator assisted nailing; mLDFA, mechanical lateral distal femoral angle.

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**Multimedia**

**Product Guide**

**Product Guide**

- BioComposite SwiveLock Anchor
- BioComposite SwiveLock C, with White/Black TigerTape™ Loop
- BioComposite SwiveLock Anchor, With Blue FiberTape Loop
- Knotless SutureTak® Anchor

**Citation**


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