## Nail Plate Fixation Versus Lateral Locked Plating for Distal Femur Fractures: A Multicenter Propensity Matched Analysis

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Distal femur fractures are devastating injuries associated with significant morbidity and mortality. Surgical management is often challenging given the displaced, intra-articular, and comminuted nature of many of these fractures. Precontoured lateral locking plates (LLP) are currently the most commonly utilized surgical option, but nail plate fixation (NPF) has recently been proposed for fracture patterns at a high risk of nonunion as a way to combine the virtues of each individual technique. The purpose of this multicenter study is to 1) report on outcomes after NPF and 2) compare nonunion and malunion rates after NPF with a propensity matched cohort of distal femur fracture patients treated with LLP.

All adult patients with distal femur fractures who underwent NPF or LLP between 2012 and 2019 at one of the 11 participating institutions were identified. Patient and injury characteristics, operative details, pre- and post-operative radiographs, and outcome variables were collected from inpatient and outpatient records. After using propensity score matching to account for risk factors for nonunion, the rates of malunion and unplanned reoperation to promote union were compared between the two treatment cohorts. Minimum follow-up was set at 12 weeks. RESULTS:

Thirty-five NPF patients (mean age 52 years old, 69% female) and 873 LLP patients met criteria for inclusion. Of the 35 fractures treated with NPF, 23 (66%) occurred due to high energy mechanisms such as motor vehicle collisions or falls from height, 20 (57%) were intra-articular, 14 (40%) were open, 4 (12%) were periprosthetic, and 21 (60%) had comminution at the medial cortex. No NPF patients required unplanned reoperation to promote union and no NPF patients exhibited varus or hyperextension malunion at final follow-up. Three underwent all-cause unplanned reoperation (2 for infection, 1 for hardware removal) at an average of 92 weeks after surgery. More than 90% were ambulatory with no or minimal pain at final follow-up (Table 1).

Propensity score matching (Figure 1) yielded well-balanced cohorts of 30 NPF patients and 30 LLP patients (Table 2). Compared to LLP patients, NPF patients demonstrated significantly lower rates of both malunion (0% vs. 13%, p=0.038) and unplanned reoperation to promote union (0% vs. 13%, p=0.038).

DISCUSSION AND CONCLUSION: This analysis of 35 patients is the largest series to date reporting on the performance of nail plate fixation for distal femur fractures. Despite a high proportion of high energy, open, and comminuted fractures, no NPF patients underwent unplanned reoperation to promote union. Furthermore, propensity score matched analysis revealed significantly lower rates of malunion or nonunion for NPF compared to LLP. These findings suggest that nail plate fixation can achieve excellent outcomes with a high rate of union for even the most complex distal femur fracture morphologies.



Age (years)     52 4/-1       Female. Scalarity     24 469       Resolution     13(8)       Black     17 (49)       Hispanic     13(8)       Tobaco Use     13(8)       Tobaco Use     16(46)       Tobaco Use     10(28)       Anierican Society of Anesthesiology Score     1       II     0 (05)       II     0 (29)       IV     410 (29)       Intra-strictular     210 (27)       Poin fracture     210 (27)       Open fracture     210 (27)       Medial Communition     21 (49)       Implant removal     31 (96)       Malainin (biperextension or varus)     0 (08)       Pain at final follow-up     51 (55)       Non-ambulatory at final follow-up     51 (59)       Non-ambulatory at final follow-up     51 (59)       None     51 (59)       None	iai acter istics		
Fende Sex     24 (69)       Race or Ethnicity     (75, 9)       Atlack     17 (36, 9)       Marking     17 (36, 9)       White     16 (46, 9)       Hispanic     17 (36, 9)       White     16 (46, 9)       Diabetes     9 (26)       Diabetes     8 (23)       American Society of Anesthesiology Scourt     10 (97, 9)       II     10 (27, 9)       II     20 (57)       IV     4 (11)       Point Society of Anesthesiology Scourt     30 (6, 4)       High energy mechanism*     24 (56)       Promote water     24 (40)       Guardian Anterna Type III     2 (55)       Vaccular Injury     5 (13)       Vaccular Injury     3 (96)       Imfaction     2 (66)       Implant removal     1 (30)       Promote union     0 (07)       Pain at field lobu-up     5 (15)       Miduin (for preparation at field follow-up     5 (15)       Miduin (for forcionally limiting     2 (77)       Severe, functionaly limiting     2 (77)	Age (years)		52 +/- 18.3
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Asian     13%)       Black in:     17(40)       Black in:     17(40)       White     16(40)       Vibite     9(26%)       Diabetics     8(2%)       American Society of Anesthesiology Score     1       I     0(05)       II     0(26%)       III     0(26%)       JIII     0(27%)       IV     4(18)       Poly Mass Index     30.64       High energy mechanism*     23.66%       Periprosthetic     41.03%       Open fracture     24.06%       Vaccular Injury     5 (15%)       Vaccular Injury     3 (0%)       Medial Commutution     2 (6%)       Implant removal     1 (3%)       Promote union     0 (0%)       Paint file of neuropy and file lolow-up     5 (15%)       Midlaun of hyperstension or varus)     0 (0%)       Paint file of neuropy and file lolow-up     5 (15%)       Midlaun of hyperstension or varus)     0 (0%)       Paint file follow-up     5 (15%)       Midlau of fule of macricanally limiting <td>Race or Ethn</td> <td>icity</td> <td></td>	Race or Ethn	icity	
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I     0.0%)       II     0.02%       III     0.02%       Body Mass Index     3.06%       Perprosthetic     4.12%       Intra-articular     4.0 (5%)       Goatilo Anderson Type III     1.2 (353)       Head Injury     5.0 (15%)       Wacular Injury     5.0 (16%)       Medial Communitution     2.0 (6%)       Implant removal     1.3 (3%)       Mulaimic Operative station     2.0 (6%)       Implant final follow-up     3.0 (9%)       Assistance     2.1 (27)       None     11.0 (27, (27)       Severe, functionally limiting     2.7 (7%)       Severe, functionally limiting     2.1 (3%)       Assistance     1.1 (3%)       None     11.0 (3%)       Mater     1.3 (45)	American So	ciety of Anesthesiology Score	
II     10 (25)       III     20 (57)       IV     4 (14)       V     4 (15)       P     10 (57)       IV     4 (15)       Body Mass Infex     106 + 4       High energy mechanism*     23 (66)       Periprototheic     4 (12%)       Intra-articular     20 (57)       Open fracture     14 (400)       Gustilo Anderson Type III     12 (55)       Medial Comminution     3 (18%)       Medial Comminution     21 (69)       Determine     12 (69)       Determine     5 (15%)       Midal comminution     2 (6%)       Implant removal     1 (38)       None     5 (15%)       Mida to functionally limiting     2 (79%)       Severe, functionally limiting     2 (79%)       None     11 (30)       None     10 (30)-9 (30%)       Asistance     12 (37)       None     11 (31)       None     11 (31)       None     11 (31)       None     11 (31)	I		0 (0%)
III     20 (57)       V     41 (11%)       V     41 (11%)       Body Mass Index     50.64       High energy mechanism     20.464       Perprosthetic     42.366       Perprosthetic     41.02       Intra-stricular     20 (57)       Open fracture     14 (40)       Head Injury     51.05       Wascular Injury     51.05       Medial Communition     21600       Dutomes     12.060       Implanned resperation     0.07%       Maluian (byperstension or varus)     0.0%       Pain at final follow-up     51.05       Non-ambulatory at final follow-up     2.06%       Mater     13.45	п		10 (29%)
IV     4 (11%)       Bdy Mass Infex     30.64/       Bdy Mass Infex     30.64/       Bdy Mass Infex     31.64/       Periprovales     21.62/       Intra-stricular     20.67/       Open fracture     20.67/       Watcolar Injury     51.63/       Vaccular Injury     51.63/       Vaccular Injury     3.0%/       Promoste union     20.67/       Promoste union     20.60/       Infraction     2.66/       Mathian Objectores     20.66/       Mathian Objectores     20.60/       Infraction     2.66/       Infraction     2.66/       Infraction     2.66/       Infraction     2.66%       Infraction     2.66%       Mathian Objow-up     5.05%       Mild on functionally limiting     2.779%       Severe, functionally limiting     2.76%       Assistance     1.03%       None     1.610/       Mater     13.435	III		20 (57%)
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Body Mass Index     30.6.4.1       High energy mechanism     23.666       Periprosthetic     41.128       Open fracture     44.600       Open fracture     14.600       Open fracture     14.600       Guistio Anderson Type III     12.6355       Head Injury     5.0158       Modial Communitution     21.600       Duronset     14.600       Promote union     0.076, Infection     2.6690, Infection       Malain of hyperextension or varus)     0.078, Severe, functionally limiting     2.7799, Severe, functionally limiting     2.779, Severe, functionally limiting     2.7690, Assistance       None     Molect     11.027, Cane or enuch     6.209, Walter     3.698,	v		1 (3%)
High energy mechanism*     23 (66)       Perprostbetic     41 (12%)       Intra-articular     20 (57)       Open fracture     14 (40)       Open fracture     14 (40)       Glead highry     5 (15%)       Wascular fujury     3 (19%)       Medial Communition     21 (607)       Ductomes     20       Unplaned responding on a straight for a straight	Body Mass I	ndex	30.6 +/- 12.8
Perprosthetic     4 (12%)       Intra-articular     4 (13%)       Intra-articular     14 (40)       Open fracture     14 (40)       Head hypen Type III     14 (40)       Head hypen Type III     15 (5%)       Wascular fnjøry     5 (15%)       Medial Communicion     2 (40)       Jutcomes     12 (40)       Infection     2 (44)       Uplanned respectation     3 (9%)       Infection     2 (6%)       Implant removal     1 (3%)       Non-ambulatory at final follow-up     5 (15%)       Non-ambulatory at final follow-up     3 (9%)       Assistance     11 (37)       Non-arout at final follow-up     3 (9%)       Assistance     11 (37)       Cane or enach     6 (20%)       Water     13 (45)	High energy	mechanism*	23 (66%)
Intra-articular     20 (57)       Open fracture     14 (400       Gustifio Anderson Type III     12 (35)       Wald Jalyury     51 (35)       Mild Comminution     2 (35)       Mild Comminution     10%       Detomest     10       Unplaned responsibility     16 (36)       Infection     2 (94%)       Infaction     1 (38)       Mathins of hyperstansion or varus)     0 (95%)       Mathins of hyperstansion or varus)     0 (95%)       None     5 (155%)       Mild, of functionally limiting     2 (79%)       Severe, functionally limiting     2 (79%)       Assistance     11 (37%)       None     11 (31)       None     11 (	Periprostheti	c	4 (12%)
Open fracture     14 (40)       Gustilo Anderson Type III     12 (35)       Head Injury     5 (13%)       Waicular Injury     3 (9%)       Midial Comminution     2 (60)       Influctorset     12 (404)       Unplanned resperation     2 (60)       Inflection     2 (60)       Inflection     2 (60)       Multiming Unpersentension or varus)     0 (9%)       Pain at final (ollow up     1 (3%)       Malunion (hyperextension or varus)     0 (9%)       None     5 (15%)       Non-ambulatory at final follow-up     2 (9%)       Assitance     11 (37)       None     10 (38)       Walker     11 (37)	Intra-articula	r	20 (57%)
Gustilo Anderson Type III     12 (35)       Head Injury     51(35)       Wedail Committoin     21(69)       Medail Committoin     12(69)       Datometry     51(35)       Valid Committoin     21(69)       Datometry     51(35)       Multiant Corporation     21(69)       Infection     2(69)       Infection     2(69)       Infection     2(69)       Multain (biperextension or varus)     0(0%)       Pain at fillar Iollow-up     5(15)       Multain (biperextension or varus)     0(0%)       Point fillar (biolow-up     2(6%)       Non-ambulatory at final follow-up     2(6%)       Assistance     11(27)       Nator     13 (45)       Walter     13 (45)	Open fractur	8	14 (40%)
Head Injury     \$ (15%)       Vascular Injury     3 (9%)       Medial Comminution     21 (607)       INCOMES     21 (4697)       INCOMES     21 (4697)       INCOMES     21 (4697)       INCOMES     21 (4697)       Include resperation     3 (9%)       Promote union     0 (9%)       Includant removal     1 (3%)       Malunion (hyperextension or varus)     0 (9%)       Pain at final follow-up     5 (15%)       Mildi, not functionally limiting     27 (79)       Severe, functionally limiting     2 (9%)       Assiance     11 437       Case or crutch     6 (25%)       Walker     13 (435)	Gustilo Ande	rson Type III	12 (35%)
Vascular fnjøry     3 (%)       Medial Committution     21 (60)       Durcomes     12 (60)       mRUST \$ 10 at 12 weeks     12 (44)       Uppart 10 at 12 weeks     12 (44)       Diplace union     10 (9)       Infection     2 (6%)       Implant removal     1 (3%)       Maluin of type seretension or varus)     0 (9%)       Pain at final follow-up     5 (15%)       Mild of functionally limiting     2 (76%)       Non-ambulatory at final follow-up     3 (9%)       Assistance     11 (37)       Cane or erutch     6 (25%)       Water     13 (45)	Head Injury		5 (15%)
Medial Comminution     21 (697)       mRUST E: 10 at 12 weeks     12 (444)       Unplaned reportation     3 (998)       Promote union     0 (908)       Infection moral     1 (897)       Multiunion (hypercentenian or varus)     0 (90%)       Pain a final follow-up     0 (90%)       Pain a final follow-up     5 (159%)       Midli, not functionally limiting     27 (797)       Severe, functionally limiting     2 (69%)       Assistance     1 (375)       None     11 (375)       None     11 (375)       Walter     13 (435)	Vascular Inju	ury	3 (9%)
Dutomes     12 (445)       mRUST 2: 10 at 12 weeks     12 (447)       Unplanned reoperation     3 (9%)       Permote union     0 (0%)       Implant removal     1 (3%)       Maluin (n) (peperetension or varus)     0 (0%)       Pain at final follow-up     5 (35,5)       None     5 (35,5)       None     2 (6%)       None     2 (6%)       Assistance     2 (6%)       None     11 (37)       Case or eratch     6 (25%)       Water     13 (45)	Medial Com	ninution	21 (60%)
mRUST z: 10 at 12 wecks     12 (44)       Uraplaned responsition     3 (9%)       Promote union     0 (0%)       Infectoria     2 (6%)       Infectoria     1 (3%)       Maint removal constance     1 (3%)       Pain a final follow-up     0 (0%)       Pain a final follow-up     5 (15%)       More     5 (15%)       None     5 (15%)       None-mobulatory at final follow-up     2 (6%)       Assistance     11 (37%)       Walter     11 (43%)       Walter     13 (435)	atcomes		
Urplanned reoperation 3 (9%) Promote union 0 (0%) Infection 2 (6%) Multimion (hyperextension or varus) 0 (0%) Pain at final follow-up None ambulant follow-up Severe, functionally limiting 27 (7%) Non-ambulanty at final follow-up 3 (9%) Assistance 11 (37%) Cance or crutch 6 (20%) Walker 12 (43%)	$mRUST \ge 10$	at 12 weeks	12 (44%)
Promote union     0.0%), Infection     0.0%), Implant removal       Matunic of typerextension or varus)     0.0%)       Pain at more or varus)     0.0%)       None     5.15%, Mild, of functionally limiting     27.79%       Severe, functionally limiting     2.6%), Non-ambulatory at final follow-up     2.6%), Assistance       None     0.00%     10.1%, Gase or enutch     6.62%, 6.62%, Walter	Unplanned re	operation	3 (9%)
Infection 2 (6%) Implant removal 1 (3%) Malunion (hyperextension or varus) 0 (0%) Pain at final clow-up None Molading 100w-up Severe, functionally limiting 27 (797) Severe, functionally limiting 2 (6%) Non-ambalatory at final follow-up Case or crutch 6 (20%) Walker 1 (3435)	Pror	note union	0 (0%)
Implant removal     1 (3%)       Malainion (bypersectension or varus)     0 (0%)       Pain at final follow-up     5 (15%)       Mildion (of necisionally limiting     27 (7%)       Severe, functionally limiting     2 (6%)       Non-ambulatory at final follow-up     3 (9%)       Assistance     11 (37)       None or entach     6 (20%)       Watter     13 (45)	Infe	ction	2 (6%)
Malunion (hyperextension or varus)     0 (0%)       Pain at final follow-up     5 (15%)       Mild, not functionally limiting     2 (7%)       Severe, functionally limiting     2 (6%)       Non-ambulatory at final follow-up     3 (9%)       Assistance     11 (37%)       Gase or crutch     6 (20%)       Walker     13 (435)	Imp	ant removal	1 (3%)
Pain at final follow-up 5 (15%   None 5 (15%   Mild, not functionally limiting 27 (79%   Severe, functionally limiting 2 (6%)   Anomebulatory at final follow-up 3 (9%)   Assistance 11 (37%)   Cance or entrch 6 (20%)   Walker 13 (43%)	Malunion (h	perextension or varus)	0 (0%)
None     5 (15%)       Mild, not functionally limiting     27 (79)       Severe, functionally limiting     2 (6%)       Non-ambulatory at final follow-up     2 (6%)       Assistance     11 (37)       Class or crutch     6 (26%)       Walter     13 (43)	Pain at final	follow-up	
Mild, not functionally limiting     27 (79%)       Severe, functionally limiting     26(%)       Non-ambulatory at final follow-up     3 (9%)       Assistance     11 (37%)       Cane or crutch     6 (20%)       Walker     13 (43%)	Non	e	5 (15%)
Severe, functionally limiting     2 (6%)       Non-ambulatory at final follow-up     3 (9%)       Assistance     11 (37)       Cane or crutch     6 (20%)       Walker     13 (439)	Mile	, not functionally limiting	27 (79%)
Non-ambulatory at final follow-up 3 (9%)   Assistance None   None 11 (37)   Cane or crutch 6 (20%)   Walker 13 (439)	Seve	re, functionally limiting	2 (6%)
Assistance 111 (37%) Cane or crutch 6 (20%) Walker 13 (43%)	Non-ambulatory at final follow-up		3 (9%)
None     11 (379       Cane or crutch     6 (20%)       Walker     13 (439)	Assistance	-	
Cane or crutch 6 (20%) Walker 13 (439)	Non	e	11 (37%)
Walker 13 (439	Can	e or crutch	6 (20%)
	Wal	ker	13 (43%)
			(10.10)
High energy injuries include automobile or motorcycle collisions, vehicle very	ligh energy injuries in	clude automobile or motorcycle colli	isions, vehicle versus

Table 2. Characteristics and Outcomes between	en Propensity Matche	opensity Matched Cohorts		
	Lateral Locked	Nail Plate (n=30)	P-Valu	
	Plate (n=30)			
Characteristics				
Age (years)	52.8 +/- 17.2	51.5 +/- 18.0	0.773	
Female Sex	15 (50%)	21 (70%)	0.114	
Body Mass Index	26.0 +/- 8.6	30.7 +/- 13.0	0.281	
High Energy Injury	20 (67%)	19 (63%)	0.787	
Periprosthetic	6 (20%)	4 (13%)	0.488	
Intra-articular	16 (53%)	17 (57%)	0.795	
Open fracture	14 (47%)	11 (37%)	0.432	
Gustilo Anderson Type III	11 (37%)	9 (30%)	0.584	
Medial Comminution	20 (67%)	20 (67%)	1.000	
Medial Translation (proportion of condylar width)	0.50	0.41	0.700	
Outcomes				
Unplanned reoperation to promote union	4 (13%)	0(0%)	0.038	
Malunion (hyperextension or varus)	4 (13%)	0(0%)	0.038	
Reoperation for infection	0 (0%)	2 (7%)	0.150	
mRUST score ≥10 at 12 weeks	11 (46%)	12 (44%)	0.921	