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Distal femoral osteotomy in a young symptomatic population: Outcomes correlate to concomitant pathology

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ABSTRACT

Background: There is a paucity of literature describing distal femoral osteotomies (DFO) in regards to complications and outcomes with previously studied cohorts containing primarily older, arthritic subjects. There has been no study to date focusing on younger, pre-arthritic patients.

Methods: All service members indicated for distal femoral osteotomy for coronal plane malalignment were isolated from military treatment centers between 2007 and 2013. Demographic and surgical variables were extracted, and perioperative complications, clinical course, and return to military function were extracted using clinical notes and radiographs.

Results: A total of 22 knees in 19 patients were identified at an average 3.2 year follow-up, with the exclusion of 16 individuals. Statistical analysis revealed worse outcomes associated with smoking, over correction, breach of the medial cortex, and prior surgeries. Overall 58% of patients left the military as the result of knee dysfunction despite an average improvement in visual analog scores (VAS) from 4.0 to 1.9 ($p = 0.004$).

Conclusions: While offloading the lateral compartment improves symptoms at short to midterm follow-up preventing progression to arthroplasty, young active duty military members have suboptimal return to duty rates.

1. Introduction

The importance of the coronal alignment of the knee is well established, with varus and valgus deformities being associated with progression of joint arthrosis in the medial and lateral compartments, respectively.[6,16,17] This is particularly true in the setting of meniscal deficiency. Symptomatic varus deformities of the knee have been historically treated with high tibial osteotomy (HTO) with robust literature available demonstrating effective offloading of the medial compartment and delays in disease progression.[1,4,12,15] The utility of HTO has also been validated in mild cases of deformity for chondroprotective measures alongside medial meniscal and cartilage procedures.[11,19,20]

Conversely, valgus deformities of the knee are comparatively less common, comprising just 10% of knees undergoing arthroplasty.[13] While varus-producing distal femoral osteotomy (DFO) is a well-accepted corrective procedure, there is a paucity of literature describing complications and outcomes. Existing studies are comprised largely of small cohorts of older and presumably lower demand demographic with more advanced arthritic wear.[7,8,21] While authors have generally reported functional improvements following DFO, there have been no studies primarily investigating younger, physically active patients treated with DFO, evaluating progression of lateral compartment arthrosis, return to activity, and effect of concomitant pathology.

The purpose of the current study was to elucidate the functional and occupational outcomes and the complication profile following DFO in a relatively young active duty military population, as well as characterize patient and surgical characteristics predictive of adverse outcomes. The primary outcomes of interest were results in the setting of concomitant pathology, ability to return to activity, and progression to revision surgery or arthroplasty.

2. Methods

The Military Health System Management Analysis and Reporting Tool (M2) was queried using the Current Procedural Terminology (CPT) code 27450 designated for distal femoral osteotomy (DFO) identifying all patients undergoing the procedure of interest throughout the military between the years 2007 and 2013. The M2 is a database capturing

This study was approved by the Institutional Review Board.

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all patients treated through the Military Health System (MHS) designed to collect demographic, clinical, and billing information. This methodology is well described and has been previously used to identify cohorts within the military.[22,24] The cohort was then cross referenced using the Armed Forces Health Longitudinal Technology Application (AHLTA version 3.6.0, 3 M Health Information Systems, Salt Lake City, UT). Inclusion criteria included any active duty service member undergoing DFO for correction of a primary valgus deformity. Exclusion criteria included any non-active duty status and/or correction of post-traumatic malunions or rotational deformity.

An extensive chart review to include operative reports, outpatient provider notes, physical therapy notes, and radiographs was performed. Patient information was gleaned to include demographics, tobacco use, surgical history, radiographic evidence of osteoarthritis, and magnitude of deformity. The deformity and post-operative correction was characterized by first establishing the mechanical axis with a line from the center of the femoral head to the center of the tibial plafond. The intersection of the mechanical axis with the tibial plateau was then scrutinized. A mechanical axis passing through the medial half of the lateral tibial plateau was assigned zone 1; an axis through the lateral half of the lateral plateau was zone 2; zone 3 was designated as any axis falling lateral to any portion of the knee joint. This method of describing coronal deformity about the knee has been previously described by Ballal et al.[2] (Fig. 1A and B). Surgical variables, including concomitant procedures, under/over correction defined as post-operative mechanical axis falling in zone 2 of valgus or medial to the intercondylar eminence in varus respeectively, change in sagittal alignment, medial cortical breach necessitating additional fixation, and bone grafting material, were obtained. Lastly clinical course was assessed to delineate the presence of perioperative complications, range of motion, time to union, subsequent procedures, return to duty, and subjective Visual Analog Scores (VAS). Primary outcomes of interest included return to duty rates, conversion to arthroplasty, and subjective scores.

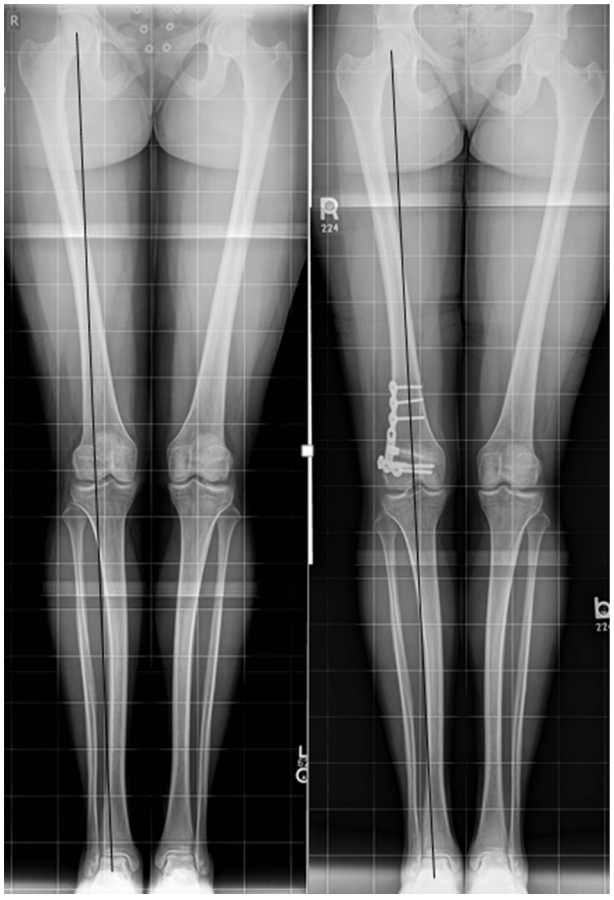

Fig. 1. AB: Ballal et al. method of describing coronal deformity.

Appropriate statistical analysis was performed with variables evaluated as continuous or discreet as indicated. Descriptive analyses with means and standard deviations (SD) or 95% confidence intervals (CI) were calculated. A univariate analysis was performed identifying pre-operative variables associated with outcomes of interest with results expressed as odds ratios (OR) or 95% CIs when appropriate. A P-value of less than 0.05 was considered statistically significant.

3. Results

3.1. Patient-associated variables

A total of 22 knees in 19 patients (3 bilateral) were identified during the study period with an average follow up time of 3.2 (0.5–6) years (Table 1). The average age was 30.0 (19–50) years, and the population was primarily male (90.9%). Seven (31.8%) patients had documented tobacco use. The majority of the cohort had prior procedures on the operative knee, the average knee undergoing 1.2 procedures prior to the DFO. These were primarily lateral meniscal debridements with 10 (45.5%) patients having a reported lateral meniscus tear requiring one or more partial debridements. Over half of the patients (54.5%) had no radiographic evidence of osteoarthritis. The remainder of which had findings of mild radiographic osteoarthritis with the exception of 3 knees that displayed more advance disease at the time of DFO. Likewise, the deformities were generally mild in nature, with most patients having a mechanical axis falling just lateral to the lateral tibial eminence.

3.2. Surgical variables

Fixation methods included lateral Puddu plate (59.1%), lateral locking plate (27.3%), medial blade plate (9.1%), and lateral Puddu plate augmented with medial fixation (4.5%) for unintentional completion of the osteotomy. The majority of surgeons opted to use allograft bone (31.8%), synthetic calcium phosphate (4.5%), or combined allograft/synthetic (36.4%) void filler at the osteotomy site. There was no use of autogenous bone graft. Sixteen (72.7%) patients had correction neutral or zone 1. The remaining 6 (27.3%) patients were over-corrected to slight varus with mechanical axis falling medial to the intercondylar eminences. Seven (31.8%) patients had concomitant procedures (excluding diagnostic arthroscopy), including 3 lateral meniscal debridements, 2 abrasion chondroplasties, 1 lateral meniscal allograft transplantation (LMAT), 1 tibial tubercle osteotomy, 1 medial patellar femoral ligament (MPFL) reconstruction, and 1 revision anterior cruciate ligament (ACL) reconstruction.

3.3. Outcomes

There were a total of 4 patients with perioperative complications, including deep venous thrombosis (DVT), superficial wound infection treated with antibiotics, delayed union, and failure of fixation for an overall complication rate of 18.1% (Table 2). Six patients had unplanned reoperations to include bone grafting of the delayed union, revision DFO for loss of correction, and 4 with removal of symptomatic hardware. Additionally 5 patients had a planned return to the operating room for staged procedures to include ACL reconstruction, osteochondral allograft transfer to the lateral femoral condyle, LMAT, medial collateral ligament (MCL) reconstruction, and MPFL reconstruction. The average time to union was 26 weeks (SD 19.2). No patient experienced nonunion. The average total arc of motion at final follow up was 3–121°. VAS scores for the knee improved from an average pre-operative score of 4.0 to 1.9 ($p = 0.004$) at final available follow up. Eleven (57.9%) patients were unable to return to active duty and were

Table 1
Patient characteristics.

#	Age	Tobacco	Prior Procedure (N)	Pre-op Valgus (Zone)	Prior OA	Fixation Method	Medial Completion	Zone after Correction	Degree of Correction	Graft	Overcorrection	Concomitant Procedure
1	28 M	N	LMD x2 (2)	2	N	locking plate	Y	1	1	allograft	N	LMAT
2	21 M	Y	LFC MFx (1)	1	N	puddu plate	N	1	0	none	N	none
3	28F	N	LMD (1)	1	Y	puddu plate	N	1	0	allograft	Y	none
4	32 M	N	None (0)	2	Y	blade plate	N	1	1	allograft	Y	none
5	21 M	Y	MMD, MCLR, ACLR (3)	2	N	puddu plate	N	1	1	synthetic, allograft	N	none
6	26 M	N	ACLR, LMD (2)	3	Y	locking plate	Y	1	2	none	N	none
7	37 M	N	LFC MFx, LB removal, Medial reefing/ lateral release x3 (5)	2	N	locking plate	N	1	1	none	N	TTO
8	44 M	Y	LMD (1)	2	Y	Locking plate	Y	1	1	none	Y	none
9	50 M	N	None (0)	3	Y	locking plate	Y	1	2	none	N	none
10	50 M	N	None (0)	3	Y	locking plate	N	1	2	allograft	N	none
11	25F	Y	LMR, MMR (2)	1	N	puddu plate	N	1	0	synthetic, allograft	N	LMD, LFC chondroplasty
12	23 M	N	None (0)	1	N	puddu, augmented with medial plate	Y	1	0	synthetic	N	none
13	27 M	Y	ACLR, LMD (2)	2	N	puddu plate	N	1	1	allograft	Y	Revision ACL recon
14	39 M	Y	LMD x2, LFC chondroplasty (3)	2	N	blade plate	Y	1	1	none	Y	LMD, chondroplasty
15	25 M	Y	LMD (1)	1	Y	puddu plate	N	1	0	Allograft	N	arthroscopy
16	32 M	N	LMD (1)	2	Y	puddu plate	Y	1	1	allograft	N	arthroscopy
17	22 M	N	LMD (1)	2	N	puddu plate	N	1	1	synthetic, allograft	Y	arthroscopy
18	23 M	N	None (0)	2	N	puddu plate	Y	1	1	synthetic, allograft	N	LMD
19	24 M	N	None (0)	1	N	puddu plate	N	1	0	synthetic, allograft	N	MPFL recon
20	19 M	N	None (0)	2	N	puddu plate	N	1	1	synthetic, allograft	N	none
21	31 M	N	LMD (1)	2	Y	puddu plate	N	1	1	synthetic, allograft	N	none
22	32 M	N	None (0)	2	Y	puddu plate	Y	1	1	synthetic, allograft	N	none

Table 2
Outcome and complications.

#	Final ROM	Pre-op VAS	Final VAS	Time to union (weeks)	Complications (N)	Reoperation (N)	Still in military @ 2yrs/final	Medical Separation
1	0–140	0	1	27	None (0)	None (0)	N/N	Y
2	0–130	5	2	9	None (0)	None (0)	Y/Y	N
3	5–120	6	6	21	DVT, impinging bone graft, symptomatic HW (3)	Bone graft resection, HWR (2)	Y/N	Y
4	0–120	6	1	37	symptomatic HW (1)	HWR (1)	Y/Y	N
5	0–135	6	4	9	None (0)	MCL, ACL recon, HWR (1)	N/N	Y
6	0–130	3	1	5	None (0)	None (0)	N/N	Y
7	0–125	0	0	9	None (0)	MPFL recon, patellar chondroplasty (1)	Y/Y	N
8	0–120	5	5	35	None (0)	None (0)	N/N	N
9	0–90	4	0	82	None (0)	None (0)	Y/N	N
10	0–90	7	0	29	None (0)	None (0)	Y/N	N
11	0–130	4	2	13	None (0)	None (0)	N/N	Y
12	0–135	0	0	19	None (0)	LFC allograft OATS (1)	Y/N	N
13	0–130	5	5	46	symptomatic HW (1)	HWR (1)	Y/N	Y
14	0–130	6	4	63	delayed union (1)	Bone grafting (1)	Y/N	Y
15	0–105	6	2	23	superficial wound infection (1)	LMAT (1)	N/N	Y
16	0–100	2	0	14	None (0)	None (0)	Y/Y	N
17	0–120	5	2	18	None (0)	None (0)	Y/N	N
18	0–100	4	2	12	None (0)	None (0)	N/N	N
19	0–135	3	1	47	malunion, symptomatic HW (2)	Revision DFO, HWR (2)	Y/Y	N
20	0–120	3	1.5	16	None (0)	LMAT, MCLR, ACLR (1)	N/N	Y
21	0–130	7	3	27	None (0)	None (0)	N/N	Y
22	0–130	0	0	15	None (0)	None (0)	N/N	Y

ROM- Range of motion.
HW(R)- Hardware (removal).

medically separated from the military due to knee related symptoms. No patients subsequently went on to knee arthroplasty within the study period.

3.4. Statistical analysis

Statistical analysis revealed several significant relationships (Table 3). Time to union was related to age ($p = 0.005$) when evaluated as a continuous variable. There was furthermore an increased risk of complications with over-correction past neutral alignment (OR 14.0; $p = 0.022$). Patients with documented tobacco use (3.4 vs 1.2; $p = 0.006$), prior procedures (2.6 vs 0.7; $p = 0.013$), and correction past neutral (3.8 vs 1.2; $p = 0.001$) reported higher average VAS scores postoperatively. Unplanned reoperation was additionally more common in patients with increased preoperative valgus ($p = 0.043$) and completion of osteotomy ($p = 0.050$). Lastly, patients with prior knee procedures were more likely to be unable to return to active duty and to undergo eventual medical separation ($p = 0.049$). Of note implant choice, bone graft material, and all remaining variables evaluated did not significantly affect any measured outcomes.

4. Discussion

In this investigation, we studied a young military cohort undergoing DFO. While the cohort had significant symptomatic improvement, there was inconsistent overall return to preoperative military function with coronal plane realignment. We identified previous surgical procedures as a predictor of inability to return to duty, as well as tobacco use and prior surgeries as a predictor of worse VAS pain scores.

Success rates following varus-producing DFO for symptomatic valgus knees have traditionally been reported at 64–92% at 10 years following surgery[7,9,10,22] (Table 4). However the patient populations under investigation were generally older, with the majority being of middle age (e.g. > 47–50 years), and with pre-existing diagnosis of

Table 3
Associations.

Predictive Variable	Time to Union	Post-op VAS	Reoperation	Complications	Return to Active Duty	Medical Separation
Age						
Continuous variable	**0.0051**	0.5528	0.2505	0.7974	0.8276	0.1892
< 30 vs ≥ 30 years	**0.0932**	0.313	0.3464	0.6593	0.3328	0.2004
Tobacco	0.7195	**0.0058**	0.4551	0.2719	0.5252	0.1813
Prior Procedures	0.2895	**0.0125**	0.7464	0.8565	0.8476	**0.04882**
Degree of pre-op valgus						
Continuous	0.2821	0.2599	**0.0426**	0.1107	0.2938	0.7335
Mod (≥1) vs Mild (1)	0.5434	0.7235	0.2325	0.1577	0.4729	1
Degree of valgus correction						
Continuous	0.2821	0.2599	**0.0426**	0.1107	0.2938	0.7335
Mod (≥1) vs Mild (1)	0.2441	0.1069	0.2571	0.5027	0.5916	0.5416
Pre-existing OA	0.2338	0.7909	0.6962	0.4882	0.4625	1
Completion of osteotomy	0.4315	0.313	**0.0501**	0.1814	0.2981	0.6651
Graft[a]	0.2707	0.9183	0.4883	0.5014	0.4729	0.3459
Overcorrection[b]	0.123	**0.0011**	0.2325	**0.0217**	0.68	1
Concomitant Procedures	0.7981	0.9431	0.6962	0.2325	0.4625	1

[a] Graft material compared to no graft material used at osteotomy site.
[b] Overcorrection defined as mechanical axis falling medial to the intercondylar eminences.

Table 4
DFO in the Literature.

Series	# of Patients	Mean Age (yr)	Mean Follow-Up	Fixation	Outcomes	Conversion to Arthroplasty (%)	Complications
Wang et al., 2005	30	53 (31–64)	99 mo (61–169)	Blade plate	Improvement in HSS knee scores, ROM arc of 124 (100–35)	3 (10%)	Not explicitly reported except 1 nonunion, 1 tibia fx
Kosashvili et al., 2009	31	45.5 (24–63)	15.1 yr (10–25)	Blade plate	Improvement in MKS scores	15 (48.5%)	Not reported
Finkelstein et al., 1996	20	59.1 (27–77)	133 mo (90–240)	Blade plate	Improvement in pain and function scores	7 (35%)	5 complications (12.5%), arthrofibrosis, infection, PE, fixation failure, femur fx
McDermott et al., 1988	24	53 (22–74)	48 mo (24–138)	Blade plate	Improvement in subjective and functional scores in all but 2 patients	1 (4.2%)	4 complications (16.6%), failure of fixation, PE, arthrofibrosis, infection
Current study	19	30 (19–50)	38.2 mo (3.5–108)	Puddu plate (59%), locking plate (27%), blade plate (9%), Puddu plate augmented with medial fixation (5%)	Improvement in subjective pain scores, poor return to military duty (42%)	0	4 complications (18.1%), infection, DVT, delayed union, failure of fixation

HSS- Hospital for Special Surgery knee score.
ROM- Range of motion.
MKS- Modified Knee Society Score.

osteoarthritis. Additionally, successful outcomes were typically defined as prevention of progression to arthroplasty. This investigation was uniquely comprised uniformly of younger, high-demand military cohort with a significantly lower average age of 30 years and with less than half of patients with radiographic evidence of lateral compartment osteoarthritis. The remaining patients with evidence of osteoarthritis had primarily mild disease. Furthermore, the population under investigation differed from historical cohorts as most DFO in this series were performed in conjunction with cartilaginous, ligamentous, meniscal procedures, or with staged additional procedures planned.

The overall complication rate of 18.1% is comparable to previously reported rates ranging from 0 to 19%.[7,8,10] All complications encountered in this cohort have furthermore been previously described in the existing literature. However, we discerned a significant association between over-correction and development of post-operative complications (OR 14.0; p = 0.022). Patients were additionally significantly more likely to report inferior VAS pain scores when over-corrected past neutral (3.8 vs1.2, p = 0.011). To our knowledge, these relationships have not been previously described in the setting of DFO. In contrast, Coventry et al.[4] described under-correction as a risk factor for clinical and surgical failure in the setting of a valgus producing HTO performed for medial osteoarthritis with a recommended over-correction of 8°. This disparity may represent differences in the patient populations under investigation, underlying pathologic entities, and ultimate treatment goals.

In regard to clinical outcomes, patients in this study experienced a significant decrease in overall VAS subjective pain scores, from an average of 4 to 1.9, following DFO. This is corroborated in the current literature, in which there is a uniform improvement in pain and other subjective functional outcome scores following DFO.[3,5,8,14] Interestingly, several factors were found to be associated with significantly inferior VAS pain scores. Patients with documented tobacco use reported higher VAS pain scores post-operatively (3.4 vs 1.2, p = 0.006). Tobacco use has previously been shown to negatively impact surgical outcomes and to be associated with an increased risk of adverse outcomes.[18] These results offer strong support for counseling on smoking cessation pre-operatively. Additionally, patients with prior procedures reported significantly higher post-operative VAS pain scores than those without prior operative treatment. These patients were furthermore significantly less likely to return to their military occupation with an overall medical separation rate of 57.9%. Patients with prior procedures likely represent knees with greater pre-existing pathological burden often affecting not only the alignment but also the meniscal, cartilaginous, and ligamentous structures of the knee. These complex problems are likely incompatible with military requirements despite the most valiant surgical attempts at reconstruction. Overall, the functional and occupational outcomes reported in this investigation compare unfavorably to existing series on DFO in older, less active individuals but also to a similar military cohort undergoing valgus-producing HTO for medial compartment pathology[23] again underscoring the unique and often complex pathology encountered in the valgus knee.

While many patients in this investigation had planned staged procedures subsequent to their DFO, 6 (27.2%) patients had unplanned reoperations. The majority of these patients underwent symptomatic hardware removal for iliotibial band irritation. Other studies report variable but often significant rates of symptomatic hardware ranging from 6 to 100%[3,5,8,14,21] necessitating frequent plate removal. Additionally, in this series, patients with larger corrections or unintentional completion of the osteotomies to the medial cortex were more likely to undergo reoperation (p = 0.043 and p = 0.050, respectively). Larger corrections result in more relative lengthening of the lateral structures as well as a more superficial position of the implants, both of which likely explain the incidence of iliotibial band irritation and subsequent requisite hardware removal.

This analysis is most limited by its retrospective nature and the inherent bias associated with any retrospective data collection.

Additionally, while comparable to existing series in contemporary DFO literature, the investigation likely lacks the power to identify more subtle but significant associations and findings. However, given the narrow indications for DFO, a larger prospective series would be difficult and no such investigation has yet been performed. Another criticism would be that the functional and occupational outcomes for our military cohort may not be extrapolated to a civilian population. However, the results within the military have often been compared to that in a young recreational or competitive athletic population. Furthermore, the authors suspect the outcomes underestimate the benefit of the surgery. Despite separation from the military, most patients had improvement in subjective symptoms. While these patients were not able to return to full military duty, they may have been able to return to less demanding activities.

5. Conclusion

Despite the relative rarity, symptomatic valgus knees represent a challenge to orthopaedic surgeons. As seen in our military cohort, these knees often present with complex combined pathology of the meniscus, cartilage, and even ligamentous structures that requires extensive reconstructive procedures in the setting of coronal plane re-alignment. While offloading the lateral compartment improves symptoms at short to midterm follow-up preventing progression to arthroplasty, young active duty military members have suboptimal return to duty rates. A patient's ability to return to the military is negatively affected by the number of procedures performed and is likely a reflection of both intra-articular pathology and the demands placed on young service members.

Disclaimers

The authors are employees of the U.S. Federal Government and the United States Army. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of William Beaumont Army Medical Center, the Department of Defense, or United States government.

Conflict of interest

The authors have no conflict of interest. We do not have any financial or personal relationships to disclose.

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