Factors Associated With Distal Femoral Osteotomy Survivorship

Data From the California Office of Statewide Health Planning and Development (OSHPD) Registry

Cory K. Mayfield,* MD, Ioanna K. Bolia,* MD, MS, PhD, Erik N. Mayer,† MD, Keemia Soraya Heidari,* MD, Nathanael Heckmann,† MD, William C. Pannell,* MD, Jeffrey Ryan Hill,* MD, Braden McKnight,* MD, C. Thomas Vangsness,* MD, George F. Hatch,* MD, and Alexander E. Weber,*‡ MD

Investigation performed at USC Epstein Family Center for Sports Medicine, Keck Medicine of USC, Los Angeles, California, USA

Background: Malalignment of the lower extremity can lead to early functional impairment and degenerative changes. Distal femoral osteotomy (DFO) can be performed with arthroscopic surgery to correct lower extremity malalignment while addressing intra-articular abnormalities or to help patients with knee osteoarthritis (OA) changes due to alignment deformities.

Purpose: To examine survivorship after DFO and identify the predictors for failure.

Study Design: Case series; Level of evidence, 4.

Methods: Data from the California Office of Statewide Health Planning and Development, a statewide discharge database, were utilized to identify patients between the ages of 18 and 40 years who underwent DFO from 2000 to 2014. Patients with a history of lower extremity trauma, infectious arthritis, rheumatological disease, skeletal dysplasia, congenital deformities, malignancy, or concurrent arthroplasty were excluded. Failure was defined as conversion to total or unicompartmental knee arthroplasty, and the identified cohort was stratified based on whether they went on to fail. Age, sex, race, diagnoses, concurrent procedures, and comorbidities were recorded for each admission. Statistically significant differences between patients who required arthroplasty and those who did not were identified using the Student *t* test for continuous variables and a chi-square test for categorical variables. Kaplan-Meier survivorship curves were constructed to estimate 5- and 10-year survival rates. A Cox proportional hazards model was used to analyze the risk for conversion to arthroplasty.

Results: A total of 420 procedures were included for analysis. Overall, 53 knees were converted to arthroplasty. The mean follow-up time was 4.8 years (range, 0.0-14.7 years). The 5-year survivorship was 90.2% (range, 85.7%-93.4%), and the 10-year survivorship was 73.2% (range, 64.7%-79.9%). The mean time to failure was 5.9 years (range, 0.4-13.9 years). Survivorship significantly decreased with increasing age ($P = .004$). Hypertension and a primary diagnosis of osteoarthrosis were significant risk factors for conversion to arthroplasty (odds ratio [OR], 3.12 [95% CI, 1.38-7.03]; $P = .006$, and OR, 2.42 [95% CI, 1.02-5.77]; $P = .045$, respectively), along with a primary diagnosis of traumatic arthropathy (OR, 10.19 [95% CI, 1.71-60.65]; $P = .01$) and a comorbid diagnosis of asthma (OR, 2.88 [95% CI, 1.23-6.78]; $P = .02$). Patients with Medicaid were less likely (OR, 0.11 [95% CI, 0.01-0.88]; $P = .04$) to undergo arthroplasty compared with patients with private insurance, while patients with workers' compensation were 3.1 times more likely (OR, 3.08 [95% CI, 1.21-7.82]; $P = .02$).

Conclusion: Older age was an independent risk factor for conversion to arthroplasty after DFO in patients $\geq$18 years but $\leq$60 years. Hypertension, asthma, and a diagnosis of osteoarthrosis or traumatic arthropathy at the time of surgery were predictors associated with failure, reinforcing the need for careful patient selection. The high survivorship rate of DFO in this analysis supports this procedure as a reasonable alternative to arthroplasty in younger patients with valgus deformities about the knee and symptomatic unicompartmental OA.

Keywords: knee osteotomy; knee arthroplasty; osteoarthritis; joint preservation; malalignment; database study

The Orthopaedic Journal of Sports Medicine, 8(9), 2325967120951554
DOI: 10.1177/2325967120951554
© The Author(s) 2020

Malalignment of the lower extremity can lead to pain, functional impairment, and early degenerative changes. Symptomatic genu varum is usually caused by excessive varus of

This open-access article is published and distributed under the Creative Commons Attribution - NonCommercial - No Derivatives License (https://creativecommons.org/licenses/by-nc-nd/4.0/), which permits the noncommercial use, distribution, and reproduction of the article in any medium, provided the original author and source are credited. You may not alter, transform, or build upon this article without the permission of the Author(s). For article reuse guidelines, please visit SAGE's website at http://www.sagepub.com/journals-permissions.

the tibia and may be treated with high tibial osteotomy, while excessive valgus malalignment about the knee is often caused by excessive valgus of the femur and is less frequently encountered. Genu valgum, whether resulting from a hypoplastic lateral femoral condyle or acquired from previous trauma or previous intra-articular procedures, may lead to early osteoarthritis (OA) of the lateral compartment.[3]

Although total knee arthroplasty or lateral unicompartmental knee arthroplasty may be employed to treat unicompartmental OA associated with a valgus deformity, their utility in younger patients with OA is limited by implant longevity and the eventual need for revision surgery.[14] Therefore, in young active patients with lateral compartment OA and valgus malalignment, correction is sometimes attempted with distal femoral osteotomy (DFO) to offload the diseased compartment.[3,17] Realignment procedures of the lower extremity, including DFO, are useful for the treatment of habitual patellar dislocations with good outcomes.[12] However, Eberbach et al,[7] in a study of 420 patients, found that valgus malalignment was more commonly caused by a tibial deformity compared with a femoral deformity. In addition, the authors suggested that varus osteotomy to address OA of the lateral compartment must be performed at the tibial site or as a double-level osteotomy procedure (femoral and tibial). Nevertheless, DFO has been shown to achieve satisfactory pain relief and functional improvement in patients with unicompartmental OA, with a complication rate comparable with that of high tibial osteotomy.[1-3,5,8,10,11]

Previous studies investigating DFO have been limited by small sample sizes, constraining the generalizability of the results, especially pertaining to survivorship estimates. In their retrospective review, Backstein et al[1] identified only 38 patients (40 knees), despite analyzing records from a 30-year time period. A systematic review[3] included 14 studies representing 236 patients (248 knees); however, 2 of the studies that provided the largest patient contributions originated from the same institution and therefore likely represented much of the same patient cohort.[1,14] Recently, Voleti et al[15] reported a 100% (13/13) return-to-sport rate in a group of athletic patients who underwent DFO. The mean age of that patient group was 24 years (range, 15-35 years), and the mean time to return to sport was 11 months (range, 9-13 months).[15] The survivorship rate after DFO in a recent systematic review ranged from 64% to 87% at 10 years, with similar rates between open and closed DFO.[9]

The aim of this study was to conduct a population-based investigation to examine survivorship after DFO and to identify the predictors for failure, defined as conversion to arthroplasty. We hypothesized that DFO would display a reasonable level of survivorship in patients aged between 18 and 60 years.

METHODS

Data from the California Office of Statewide Health Planning and Development (OSHPD), a mandatory statewide discharge database, were utilized for this study. This database contains information from all public and private inpatient hospitals, ambulatory surgery centers, and emergency departments in the state of California, as well as demographic data for each patient and up to 25 medical diagnoses and total hospital charges with each admission. Diagnosis and procedure codes are listed as International Classification of Diseases, Ninth Revision (ICD-9) and Current Procedural Terminology (CPT) billing codes. Patients are tagged with a unique record linkage number that remains consistent throughout all admissions within the state of California, allowing patients to be tracked longitudinally regardless of where they receive postsurgical follow-up or future medical care.

Patients who underwent DFO from 2000 to 2014 were collected by identifying all admissions containing ICD-9 procedure codes 77.25 (osteotomy, femur) and 77.35 (wedge osteotomy, femur) as well as CPT codes 27448 (osteotomy, femur, without fixation) and 27450 (osteotomy, femur, with fixation). Those with a history of lower extremity trauma, infectious arthritis, rheumatological disease, skeletal dysplasia, congenital deformities, malignancy, or concurrent arthroplasty were excluded. A full list of inclusion and exclusion codes is provided in the Appendix. Patients younger than 18 years and older than 60 years were also excluded (Table 1). Concurrent diagnosis and procedure codes were reviewed for all patients with 2 qualifying osteotomy procedures to determine whether the second DFO procedure should be categorized as a revision or contralateral procedure.

From 2000 to 2014, there were 6911 procedures identified based on coding alone. However, only 420 procedures remained after exclusions (Figure 1). Over 6000 procedures were excluded by age alone. Of the procedures included for analysis, 17 patients underwent bilateral DFO.

Failure was defined as conversion to total or unicompartmental knee arthroplasty, and the identified cohort was

‡Address correspondence to Alexander E. Weber, MD, USC Epstein Family Center for Sports Medicine, Keck Medicine of USC, 1520 San Pablo Street, #2000, Los Angeles, CA 90033, USA (email: weber.ae@gmail.com).

*USC Epstein Family Center for Sports Medicine, Keck Medicine of USC, Los Angeles, California, USA.

†Department of Orthopaedic Surgery, University of California–Los Angeles, Los Angeles, California, USA.

Final revision submitted April 10, 2020; accepted April 14, 2020.

One or more of the authors has declared the following potential conflict of interest or source of funding: N.H. has received educational support from Smith & Nephew. W.C.P. has received hospitality payments from Zimmer Biomet. J.R.H. has received educational support from Elite Orthopaedics. C.T.V. has received consulting fees and honoraria from Osiris Therapeutics. G.F.H. has received educational support from Arthrex and Micromed, speaking fees from Arthrex, and honoraria from Fidia Pharma. A.E.W. has received educational support and speaking fees from Arthrex and hospitality payments from Stryker. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval was not sought for the present study.

TABLE 1
Inclusion and Exclusion Criteria[a]

Inclusion Criteria	Exclusion Criteria
Patients who underwent DFO from 2000 to 2014 (OSHPD database)	Patients aged <18 years and >60 years
Adult patients aged ≤60 years	Patients with a history of lower extremity trauma, infectious arthritis, rheumatological disease, skeletal dysplasia, congenital deformity, malignancy, or concurrent arthroplasty
Inclusion of ICD-9 procedure codes 77.25 (osteotomy, femur) and 77.35 (wedge osteotomy, femur) and CPT codes 27448 (osteotomy, femur, without fixation) and 27450 (osteotomy, femur, with fixation)	

[a]CPT, Current Procedural Terminology; DFO, distal femoral osteotomy; ICD-9, International Classification of Diseases, Ninth Revision; OSHPD, Office of Statewide Health Planning and Development.

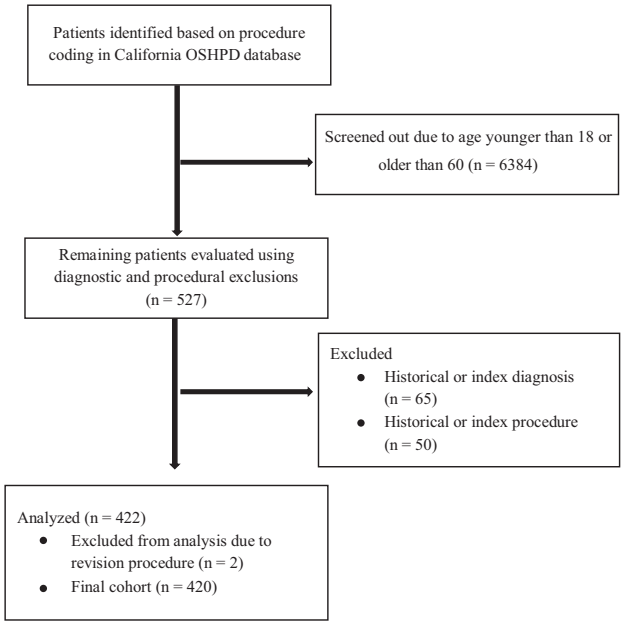

Figure 1. Patient identification and screening flow diagram. OSHPD, Office of Statewide Health Planning and Development.

stratified based on whether they went on to fail. Because of inherent limitations of the OSHPD database, we were unable to record the laterality of the procedure. Age, sex, race, diagnoses (OA, acquired genu valgum, other acquired deformity, derangement of internal knee structures, osteochondral defects, traumatic arthritis, and other arthropathy), concurrent procedures (arthroscopic surgery, osteochondral grafting, synovectomy, and meniscectomy), and comorbidities (asthma, chronic kidney disease, congestive heart failure, depression, diabetes mellitus, hypertension, obesity, and peripheral vascular disease) were recorded for each admission. Subsequent readmissions to an inpatient hospital, ambulatory surgery center, or emergency department in California after the index procedure were identified and sequenced using the record linkage number.

Statistically significant differences between patients who required arthroplasty and those who did not were identified using the Student *t* test for continuous variables and a chi-square test for categorical variables. Kaplan-Meier survivorship curves were constructed to estimate 5- and 10-year survival rates. If a patient underwent multiple revision procedures, only the time to the index arthroplasty procedure was included for analysis. Patients who underwent bilateral osteotomy were considered as 2 separate patients from the time of their contralateral DFO, to maintain the single failure per DFO procedure model. To compare survivorship for specified groups, a log-rank test of equality was employed. A Cox proportional hazards model was used to analyze the risk for conversion to arthroplasty. The results of this model were expressed as hazard ratios (HRs) with 95% CIs and *P* values. With simple Cox regression (unadjusted), we analyzed the following factors: age, sex, race, primary health insurance, diagnoses, comorbidities, and concurrent procedures. A multiple Cox regression model (adjusted) was constructed using all of these variables. Subsequent analysis using both simple and multiple Cox regression models was performed to evaluate the effect of age group (18-29, 30-39, 40-49, and 50-60 years) as well as the number of concurrent comorbidities. Statistical significance was set at $P < .05$. All statistical analyses were performed using Stata/IC 16.1 software (StataCorp).

RESULTS

From 2000 to 2014, a total of 420 procedures remained after exclusions and were included for analysis. Overall, 53 knees were converted to arthroplasty. The mean follow-up time was 4.8 years (range, 0.0-14.7 years).

Patient Characteristics

Patients who underwent an arthroplasty procedure after their DFO tended to be older than patients who did not (mean age, 43.6 ± 8.9 vs 36.8 ± 11.1 years, respectively; $P < .001$). Patients who converted to arthroplasty also had a higher incidence of hypertension (32.1% vs 10.9%, respectively; $P < .001$) and a higher number of comorbidities (47.2% vs 27.5%, with at least 1 comorbidity, respectively; $P = .021$). These patients who converted to arthroplasty were also more likely to have a diagnosis of osteoarthrosis at the time of their initial DFO (81.1% vs 53.7%, respectively; $P < .001$). Patient characteristics are listed in detail in Tables 2 and 3.

TABLE 2
Patient Demographics[a]

	Total Cohort (N = 420)	Arthroplasty (n = 53)	Nonarthroplasty (n = 367)	*P* Value
Age, mean ± SD, y	37.7 ± 11.06	43.6 ± 8.88	36.8 ± 11.10	**<.001**
Sex				.610
Male	188 (44.76)	22 (41.51)	166 (45.23)	
Female	232 (55.24)	31 (58.49)	201 (54.77)	
Race				.186
White	244 (58.10)	28 (52.83)	216 (58.86)	
Black	38 (9.05)	4 (7.55)	34 (9.26)	
Hispanic	69 (16.43)	7 (13.21)	62 (16.89)	
Asian	15 (3.57)	1 (1.89)	14 (3.81)	
Other	12 (2.86)	3 (5.66)	9 (2.45)	
Primary health insurance				.534
Medicare	18 (4.29)	1 (1.89)	17 (4.63)	
Medicaid	31 (7.38)	1 (1.89)	30 (8.17)	
Private	293 (69.76)	40 (75.47)	253 (68.94)	
Workers' compensation	51 (12.14)	9 (16.98)	42 (11.44)	
Self-pay	2 (0.48)	0 (0.00)	2 (0.54)	
Other	21 (5.00)	2 (3.77)	19 (5.18)	

[a]Data are shown as n (%) unless otherwise indicated. Bolded *P* values indicate statistically significant differences between the arthroplasty and nonarthoplasty groups ($P < .05$).

TABLE 3
Comorbidities, Diagnoses, and Concurrent Procedures[a]

	Total Cohort	Arthroplasty	Nonarthroplasty	*P* Value
Comorbidities				
Obesity	46 (10.95)	4 (7.55)	42 (11.44)	.488
Hypertension	57 (13.57)	17 (32.08)	40 (10.90)	**<.001**
Diabetes mellitus	10 (2.38)	2 (3.77)	8 (2.18)	.366
Depression	13 (3.10)	3 (5.66)	10 (2.72)	.218
Asthma	45 (10.71)	9 (16.98)	36 (9.81)	.115
Chronic kidney disease	3 (0.71)	0 (0.00)	3 (0.82)	>.999
Congestive heart failure	1 (0.24)	0 (0.00)	1 (0.27)	>.999
No. of comorbidities				**.021**
None	294 (70.00)	28 (52.83)	266 (72.48)	
1	89 (21.19)	18 (33.96)	71 (19.35)	
2	26 (6.19)	4 (7.55)	22 (5.99)	
3	10 (2.38)	3 (5.66)	7 (1.91)	
4	1 (0.24)	0 (0.00)	1 (0.27)	
Diagnoses				
Osteoarthrosis	240 (57.14)	43 (81.13)	197 (53.68)	**<.001**
Other acquired deformity	121 (28.81)	18 (33.96)	103 (28.07)	.376
Derangement of internal structures	75 (17.86)	10 (18.87)	65 (17.71)	.837
Osteochondral defect	61 (14.52)	4 (7.55)	57 (15.53)	.146
Traumatic arthropathy	10 (2.38)	2 (3.77)	8 (2.18)	.366
Other arthropathy	56 (13.33)	1 (1.89)	55 (14.99)	**.009**
Concurrent procedures				
Arthroscopic surgery	66 (15.71)	6 (11.32)	60 (16.35)	.347
Osteochondral grafting	89 (21.19)	13 (24.53)	76 (20.71)	.525
Synovectomy	16 (3.81)	2 (3.77)	14 (3.81)	>.999
Meniscectomy	48 (11.43)	6 (11.32)	42 (11.44)	>.999

[a]Data are shown as n (%). Bolded *P* values indicate statistically significant differences between the arthroplasty and nonarthoplasty groups ($P < .05$).

Risk of Conversion to Arthroplasty

Crude HR analysis demonstrated that patients were 3% more likely to undergo arthroplasty for each additional year of age (hazard ratio [HR], 1.03 [95% CI, 0.99-1.06]; $P = .05$). Patients indicated for DFO with a primary diagnosis of osteoarthrosis were 2.4 times more likely to convert to arthroplasty (OR, 2.40 [95% CI, 1.16-4.95]; $P = .02$).

TABLE 4
Simple and Multiple Cox Regression[a]

	Simple Cox Regression[b]		Multiple Cox Regression[c]	
	HR (95% CI)	*P* Value	HR (95% CI)	*P* Value
Age	1.03 (0.99-1.06)	.05	1.01 (0.98-1.04)	.59
Sex				
Male	Reference		Reference	
Female	1.22 (0.69-2.16)	.49	1.58 (0.81-3.06)	.18
Race				
White	Reference		Reference	
Black	0.64 (0.23-1.80)	.40	0.60 (0.18-2.04)	.41
Hispanic	0.63 (0.27-1.50)	.30	0.75 (0.28-2.02)	.57
Asian	1.69 (0.23-12.49)	.61	4.20 (0.50-36.62)	.18
Other	0.45 (0.06-3.26)	.43	0.73 (0.09-5.62)	.76
Primary health insurance				
Medicare	0.68 (0.31-1.48)	.33	0.48 (0.18-1.25)	.13
Medicaid	0.14 (0.02-1.06)	.06	0.11 (0.01-0.88)	**.04**
Private	Reference		Reference	
Workers' compensation	2.15 (0.93-4.95)	.07	3.08 (1.21-7.82)	**.02**
Self-pay	0.21 (0.03-1.55)	.13	0.21 (0.03-1.61)	.13
Other	0.60 (0.08-4.45)	.62	0.75 (0.09-6.46)	.79
Diagnosis[d]				
Osteoarthrosis	2.40 (1.16-4.95)	**.02**	2.42 (1.02-5.77)	**.045**
Other acquired deformity	1.02 (0.55-1.87)	.64	0.92 (0.46-1.87)	.84
Derangement of internal structures	0.86 (0.41-1.80)	.70	1.46 (0.39-5.55)	.57
Osteochondral defect	0.67 (0.24-1.85)	.44	0.93 (0.29-3.00)	.91
Traumatic arthropathy	1.53 (0.37-6.33)	.56	10.19 (1.71-60.65)	**.01**
Comorbidity[d,e]				
Obesity	0.54 (0.17-1.75)	.31	0.37 (0.97-1.47)	.16
Hypertension	2.51 (1.32-4.74)	**.005**	3.12 (1.38-7.03)	**.006**
Diabetes mellitus	1.36 (0.19-9.94)	.76	1.32 (0.12-14.16)	.82
Depression	3.02 (0.93-9.82)	.07	2.92 (0.75-11.38)	.12
Asthma	1.87 (0.87-4.01)	.11	2.88 (1.23-6.78)	**.02**
Concurrent procedure[d]				
Arthroscopic surgery	0.57 (0.24-1.35)	.20	0.34 (0.13-0.87)	**.02**
Osteochondral grafting	0.91 (0.47-1.75)	.78	0.64 (0.31-1.32)	.23
Synovectomy	0.62 (0.08-4.47)	.63	0.44 (0.05-4.15)	.47
Meniscectomy	0.69 (0.27-1.75)	.43	0.40 (0.08-1.96)	.26

[a]Bolded *P* values indicate statistical significance. HR, hazard ratio.
[b]Crude (unadjusted).
[c]Adjusted (all variables mentioned above entered into Cox analysis).
[d]Analyzed as separate independent variables given the possibility of concomitant presence in each patient.
[e]Chronic kidney disease and congestive heart failure omitted because of insufficient prevalence.

Hypertensive patients were 2.5 times as likely to require arthroplasty (OR, 2.51 [95% CI, 1.32-4.74]; $P = .005$).

When utilizing multiple Cox regression to calculate the adjusted risk of conversion to arthroplasty, hypertension and a primary diagnosis of osteoarthrosis remained significant risk factors (OR, 3.12 [95% CI, 1.38-7.03]; $P = .006$, and OR, 2.42 [95% CI, 1.02-5.77]; $P = .045$, respectively). Age was no longer a significant risk factor (OR, 1.01 [95% CI, 0.98-1.04]; $P = .59$). Furthermore, patients with Medicaid were less likely (OR, 0.11 [95% CI, 0.01-0.88]; $P = .04$) to undergo arthroplasty compared with patients with private insurance, while patients with workers' compensation were 3.1 times more likely (OR, 3.08 [95% CI, 1.21-7.82]; $P = .02$). Additional significant risk factors for conversion to arthroplasty according to multiple Cox analysis were a primary diagnosis of traumatic arthropathy (OR, 10.19 [95% CI, 1.71-60.65]; $P = .01$) and a comorbid diagnosis of asthma (OR, 2.88 [95% CI, 1.23-6.78]; $P = .02$). A full list of HRs can be found in Table 4.

On subanalysis of age groups (18-29, 30-39, 40-49, and 50-60 years), there was a significantly increased risk in each group compared with the 18 to 29–year age group (Table 5). When analyzing for the risk of multiple comorbidities, multiple Cox regression demonstrated that patients with 3 comorbidities were 6.6 times as likely to convert to arthroplasty compared with those without comorbidities (OR, 6.62 [95% CI, 1.21-36.37]; $P = .03$) (Table 5).

Survivorship

The 5-year survivorship was 90.2% (range, 85.7%-93.4%), and the 10-year survivorship rate was 73.2% (range, 64.7%-79.9%) (Figure 2). The mean time to failure

TABLE 5
Subgroup Analysis Using Simple and Multiple Cox Regression[a]

	Simple Cox Regression[b]		Multiple Cox Regression[c]	
	HR (95% CI)	*P* Value	HR (95% CI)	*P* Value
Age group, y				
18-29	Reference		Reference	
30-39	6.27 (1.42-27.59)	**.015**	6.22 (1.32-29.09)	**.02**
40-49	7.32 (1.72-31.19)	**.007**	5.00 (1.11-22.49)	.036
50-60	10.21 (2.26-46.07)	**.003**	6.94 (1.40-34.39)	.018
No. of comorbidities				
None	Reference		Reference	
1	1.69 (0.91-3.12)	.099	1.82 (0.91-3.63)	.092
2	1.75 (0.53-5.81)	.359	2.24 (0.56-8.98)	.256
3	3.67 (0.86-15.56)	.079	6.62 (1.21-36.37)	**.03**
4	0.00 (0.00-0.00)	>.999	0.26	

[a]Bolded *P* values indicate statistical significance. HR, hazard ratio.
[b]Crude (unadjusted).
[c]Adjusted (computed using multiple Cox model presented in Table 4).

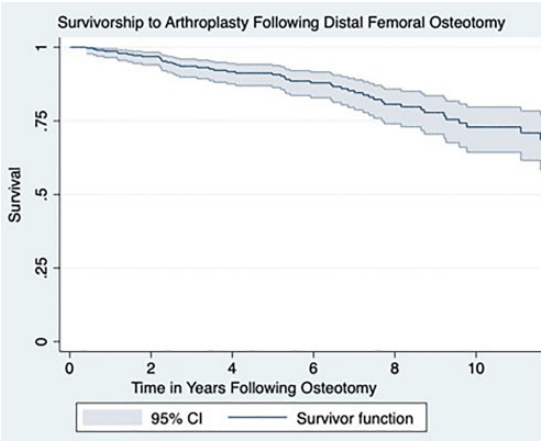

Figure 2. Kaplan-Meier survival estimate for survivorship to knee arthroplasty after distal femoral osteotomy.

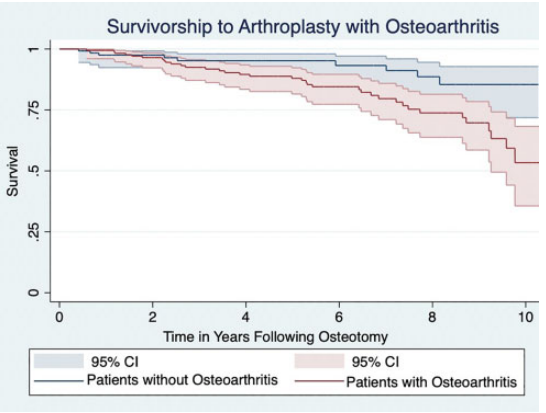

Figure 3. Kaplan-Meier survival estimate for survivorship to knee arthroplasty after distal femoral osteotomy based on diagnosis of osteoarthritis.

(ie, conversion to arthroplasty) was 5.9 years (range, 0.4-13.9 years). Patients with a diagnosis of osteoarthrosis at the time of their index procedure had a 5-year survivorship of 88.49% (range, 73.82%-93.18%) compared with 93.50% (range, 85.65%-97.12%) for patients without and a 10-year survivorship of 67.32% (range, 56.52%-76.00%) compared with 86.37% (range, 73.82%-93.18%), respectively ($P = .012$) (Figure 3). Survivorship also significantly decreased with increasing age ($P = .004$) (Figure 4).

DISCUSSION

According to this OSHPD analysis, the 5- and 10-year survivorship of DFO in patients between 18 and 60 years were 90.2% and 73.2%, respectively. Risk factors for conversion to arthroplasty after DFO were older age, hypertension, a primary diagnosis of osteoarthrosis or traumatic arthropathy, and a comorbid diagnosis of

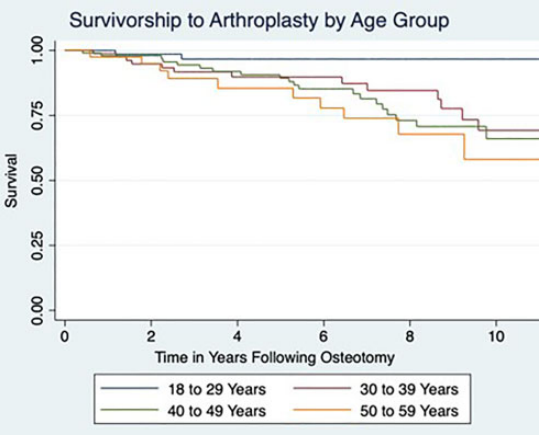

Figure 4. Kaplan-Meier survival estimate for survivorship to knee arthroplasty after distal femoral osteotomy by age group.

asthma. Patients with Medicaid were less likely to undergo arthroplasty compared with patients with private insurance, while patients with workers' compensation were 3.1 times more likely.

The survivorship rates in the current study are consistent with reports in the existing literature. Ekeland et al,[8] in a study including 24 patients with a mean age of 48 years, reported the DFO survival rate as 88% at 5 years and 74% at 10 years. Similarly, in the study of Sternheim et al,[14] the survivorship of DFO at 10, 15, and 20 years was 90%, 79%, and 21.5%, respectively. In their systematic review, Chahla et al[3] included the results of 14 studies investigating DFO for the treatment of genu valgum with lateral OA. Overall, 5 of the studies used a lateral opening wedge technique, and 9 studies utilized a medial closing wedge technique, with a total cohort of 307 patients (323 knees). They reported a mean survival rate of 80% (range, 64%-90%) at 10 years.[3] We did not report survivorship at 20 years, which seems to be significantly lower than the survival rate at 5, 10, and 15 years in previous studies.[14,16] The last point should be taken into consideration during patient counseling regarding the longevity of DFO, especially beyond 15 years from the time it was performed.

As mentioned previously, DFO is not only indicated in patients with established OA in the lateral compartment, but it is also useful as an adjunct procedure for the correction of realignment in knee preservation cases of cartilage or meniscal transplantation. Drexler et al[6] reported a survivorship of 88.9% at 10 years, 71.4% at 15 years, and 23.8% at 20 years in a group of patients who underwent DFO combined with osteochondral allograft for failed lateral tibial plateau fractures. A significant drop in the survival rate at 20 years was observed, which corroborates the findings of the studies mentioned previously. Cameron et al[2] reported their outcomes of DFO by dividing the patient cohort into a joint preservation group (cartilage or meniscal defect with a valgus deformity) and an OA group (lateral compartment OA with a valgus deformity). The authors reported a 5-year survivorship of DFO of 74% in the OA group and 92% in the joint preservation group. To our knowledge, no other research group has reported comparative outcomes based on the preoperative diagnosis or procedures performed in patients who underwent DFO. Our results showed that a similar percentage of patients in the arthroplasty and nonarthroplasty groups had osteochondral allograft transplantation performed at the time of DFO. However, we calculated the survival rates in patients who underwent DFO concurrently with other procedures, and this constitutes a limitation in our analysis.

An additional 2 studies have investigated the outcomes of DFO in young and active patients by reporting the rate of return to physical activity postoperatively. In the study of de Carvalho et al,[4] there was a significant improvement in the Lysholm score (mean postoperative score was 77.1 compared with 53.1 preoperatively) in 26 patients who underwent DFO for symptomatic OA of the lateral compartment of the knee and who were physically active. In that group, the rate of return to physical activity was 57.7% at a mean follow-up time of 48 months. More recently, Voleti et al[15] reported a 100% rate of return to sport at a mean time of 11 months in 13 patients who underwent DFO for unloading valgus knee malalignment. Of those patients, 9 (69.2%) had concomitant chondral, meniscal, or ligamentous procedures performed on the ipsilateral knee joint. Our study did not evaluate the level of physical activity of the included patients or the rate of return to physical activity, and we were unable to compare our results. More research is necessary to determine whether DFO should be routinely performed in athletes with lower extremity malalignment who wish to return to physical activity, but these past 2 studies showed promising outcomes.[4,15]

Our analysis revealed age as an independent predictor for failure. On subanalysis of age groups (18-29, 30-39, 40-49, and 50-60 years), there was a significantly increased risk in each group compared with the 18 to 29–year age group. Because of small cohort numbers, previous studies have been unable to draw associations between poor outcomes and age.[6] In the 14 studies they reviewed, Chahla et al[3] found no stratification of survival rates based on age. While decreased survivorship in the presence of OA is well documented in the high tibial osteotomy literature, such reports are fairly scarce with regard to DFO procedures. As mentioned above, Cameron et al[2] reported a 5-year survival rate of 74% in their OA group compared with 92% in the group without radiographic signs of OA. Similar to our findings, the mean age of the OA group was significantly higher than in the group without OA (41 vs 26 years, respectively).

Our results also showed that hypertension and a primary diagnosis of osteoarthrosis were significant risk factors for conversion to arthroplasty (OR, 3.12 [95% CI, 1.38-7.03]; $P = .006$, and OR, 2.42 [95% CI, 1.02-5.77]; $P = .045$, respectively). Additional significant risk factors for conversion to arthroplasty included a primary diagnosis of traumatic arthropathy (OR, 10.19 [95% CI, 1.71-60.65]; $P = .01$) and a comorbid diagnosis of asthma (OR, 2.88 [95% CI, 1.23-6.78]; $P = .02$). Unfortunately, we did not record body mass index, and therefore, we could not evaluate whether patients with metabolic syndrome are at a higher risk of DFO failure.[13] In addition, we are not aware of whether these patients were appropriately treated for hypertension. Based on the above and given that no previous studies have conducted a similar investigation, we were unable to make any conclusions regarding the impact of hypertension on the survival rate of DFO.

Our study has several strengths that are worth noting. The utilization of a statewide database allowed us to assess a larger cohort than previous studies. The larger numbers identified in the present study provided increased power to identify the risk factors for failure. Furthermore, patients identified in the current study came from several different hospitals and various practice settings throughout the state of California, making our findings more generalizable than previous single-center studies. Additionally, the unique record linkage numbers used in the OSHPD database allowed for long-term follow-up while limiting attritional loss of patient data. To our

knowledge, this is the first epidemiological study investigating the survivorship of DFO using a population cohort.

There are several limitations to this study. Administrative databases such as the OSHPD do not allow for the assessment of outcome scores, severity of the deformity, grading of OA, surgical technique, postoperative protocols, or patient activity level, which limits the level of detail provided in our analysis. Despite this limitation, we were able to estimate procedure survivorship and demonstrate an age-dependent risk of failure. With any administrative data that rely on ICD-9 and CPT coding, there is a risk of coding errors. This risk is inherent with any study that relies on these types of databases, together with the possible loss to follow-up that might have resulted in overestimation of the survivorship rates. In contrast, the lack of laterality data in the database constitutes a major limitation of this study, which might have affected the accuracy of the reported survival rates. Patient body mass index was not recorded in our analysis. Because of this, not only were we unable to provide any information on whether obesity was a risk factor for DFO failure, but we also could not examine the impact of metabolic syndrome on DFO outcomes. We did not have any information on the treatment that the included patients received for hypertension, and although hypertension was found to increase the risk for knee replacement after DFO, we were unable to make any valid conclusion. In addition, we did not have any information on the degree of knee OA of the included patients, and we were unable to identify the primary indication for DFO in our study population. Regarding the endpoint used to define failure (knee arthroplasty), we could not identify whether this was unicompartmental knee arthroplasty or total joint replacement, which would be clinically useful.

CONCLUSION

Older age was an independent risk factor for conversion to arthroplasty after DFO in patients between 18 and 60 years. Hypertension, asthma, and a diagnosis of osteoarthrosis or traumatic arthropathy at the time of surgery were predictors associated with failure, reinforcing the need for careful patient selection. The high survivorship rate of DFO supports this procedure as a reasonable alternative to arthroplasty in younger patients with a valgus deformity about the knee and symptomatic unicompartmental OA.

ACKNOWLEDGMENT

The authors acknowledge the Cappo Family Research Fund.

REFERENCES

1. Backstein D, Morag G, Hanna S, Safir O, Gross A. Long-term follow-up of distal femoral varus osteotomy of the knee. *J Arthroplasty*. 2007; 22(4 Suppl 1):2-6.
2. Cameron JI, McCauley JC, Kermanshahi AY, Bugbee WD. Lateral opening-wedge distal femoral osteotomy: pain relief, functional improvement, and survivorship at 5 years. *Clin Orthop Relat Res*. 2015;473(6):2009-2015.
3. Chahla J, Mitchell JJ, Liechti DJ, et al. Opening-and closing-wedge distal femoral osteotomy: a systematic review of outcomes for isolated lateral compartment osteoarthritis. *Orthop J Sports Med*. 2016; 4(6):2325967116649901.
4. de Carvalho LH, Temponi EF, Soares LFM, Gonçalves MBJ, Costa LP. Physical activity after distal femur osteotomy for the treatment of lateral compartment knee osteoarthritis. *Knee Surg Sports Traumatol Arthrosc*. 2014;22(7):1607-1611.
5. Delva ML, Samuel LT, Roth A, Yalçin S, Kamath AF. Contemporary knee osteotomy in the United States: high tibial osteotomy and distal femoral osteotomy have comparable complication rates despite differing demographic profiles. *J Knee Surg*. Published online November 27, 2019. doi:10.1055/s-0039-3400742
6. Drexler M, Gross A, Dwyer T, et al. Distal femoral varus osteotomy combined with tibial plateau fresh osteochondral allograft for post-traumatic osteoarthritis of the knee. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(5):1317-1323.
7. Eberbach H, Mehl J, Feucht MJ, Bode G, Südkamp NP, Niemeyer P. Geometry of the valgus knee: contradicting the dogma of a femoral-based deformity. *Am J Sports Med*. 2017;45(4):909-914.
8. Ekeland A, Nerhus TK, Dimmen S, Heir S. Good functional results of distal femoral opening-wedge osteotomy of knees with lateral osteoarthritis. *Knee Surg Sports Traumatol Arthrosc*. 2016;24(5): 1702-1709.
9. Kim YC, Yang J-H, Kim HJ, et al. Distal femoral varus osteotomy for valgus arthritis of the knees: systematic review of open versus closed wedge osteotomy. *Knee Surg Relat Res*. 2018;30(1):3.
10. Liska F, Voss A, Imhoff FB, Willinger L, Imhoff AB. Nonunion and delayed union in lateral open wedge distal femoral osteotomies: a legitimate concern? *Int Orthop*. 2018;42(1):9-15.
11. Nelson CL, Saleh KJ, Kassim RA, et al. Total knee arthroplasty after varus osteotomy of the distal part of the femur. *J Bone Joint Surg Am*. 2003;85(6):1062-1065.
12. Shen H-C, Chao K-H, Huang G-S, Pan R-Y, Lee C-H. Combined proximal and distal realignment procedures to treat the habitual dislocation of the patella in adults. *Am J Sports Med*. 2007;35(12): 2101-2108.
13. Sherling DH, Perumareddi P, Hennekens CH. Metabolic syndrome. *J Cardiovasc Pharmacol Ther*. 2017;22(4):365-367.
14. Sternheim A, Garbedian S, Backstein D. Distal femoral varus osteotomy: unloading the lateral compartment. Long-term follow-up of 45 medial closing wedge osteotomies. *Orthopedics*. 2011;34(9): e488-e490.
15. Voleti PB, Wu IT, Degen RM, et al. Successful return to sport following distal femoral varus osteotomy. *Cartilage*. 2019;10(1):19-25.
16. Wang JW, Hsu CC.Distal femoral varus osteotomy for osteoarthritis of the knee. *J Bone Joint Surg Am*. 2005;87(1):127-133.
17. Wylie JD, Maak TG. Medial closing-wedge distal femoral osteotomy for genu valgum with lateral compartment disease. *Arthrosc Tech*. 2016;5(6):e1357-e1366.

APPENDIX
Coding Algorithms

Inclusion Procedures

CPT

27448 Osteotomy, femur, shaft or supracondylar, without fixation
27450 Osteotomy, femur, shaft or supracondylar, with fixation

ICD-9

77.25 Wedge osteotomy, femur
77.35 Osteotomy, femur

Inclusion Diagnosis: Osteoarthritis

ICD-9

715.00 Osteoarthrosis, generalized, site unspecified
715.09 Osteoarthrosis, generalized, multiple sites
715.10 Osteoarthrosis, localized, primary, site unspecified
715.15 Osteoarthrosis, localized, primary, pelvic region and thigh
715.16 Osteoarthrosis, localized, primary, lower leg
715.18 Osteoarthrosis, localized, primary, other specified sites
715.20 Osteoarthrosis, localized, secondary, site unspecified
715.25 Osteoarthrosis, localized, secondary, pelvic region and thigh
715.26 Osteoarthrosis, localized, secondary, lower leg
715.28 Osteoarthrosis, localized, secondary, other specified sites
715.30 Osteoarthrosis, localized, primary or secondary, site unspecified
715.35 Osteoarthrosis, localized, primary or secondary, pelvic region and thigh
715.36 Osteoarthrosis, localized, primary or secondary, lower leg
715.38 Osteoarthrosis, localized, primary or secondary, other specified sites
715.80 Osteoarthrosis involving more than 1 site, not generalized, site unspecified
715.89 Osteoarthrosis, not generalized, multiple sites
715.90 Osteoarthrosis, generalized or localized, site unspecified
715.95 Osteoarthrosis, generalized or localized, pelvic region and thigh
715.96 Osteoarthrosis, generalized or localized, lower leg
715.98 Osteoarthrosis, generalized or localized, other specified sites

Inclusion Diagnosis: Genu Varum

ICD-9

736.41 Genu valgum (acquired)

Inclusion Diagnosis: Other Acquired Deformity

ICD-9

736.39 Other acquired deformities of hip/thigh
736.42 Genu varum (acquired)
736.5 Genu recurvatum (acquired)
736.6 Other acquired deformities of knee
736.81 Unequal leg length (acquired)
736.89 Other acquired deformity of other parts of limb
736.9 Acquired deformity of limb, site unspecified
738.8 Acquired deformity of other specified site
738.9 Acquired deformity of unspecified site

Inclusion Diagnosis: Derangement of Internal Knee Structures

ICD-9

717.0 Old bucket-handle tear of medial meniscus
717.1 Derangement of anterior horn of medial meniscus
717.2 Derangement of posterior horn of medial meniscus
717.3 Other and unspecified derangement of medial meniscus
717.40 Derangement of lateral meniscus, unspecified
717.41 Bucket-handle tear of lateral meniscus
717.42 Derangement of anterior horn of lateral meniscus
717.43 Derangement of posterior horn of lateral meniscus
717.49 Other derangement of lateral meniscus
717.5 Derangement of meniscus, not elsewhere classified
717.6 Loose body in knee
717.81 Old disruption of LCL
717.82 Old disruption of MCL
717.83 Old disruption of ACL
717.84 Old disruption of PCL
717.89 Other internal derangement of knee
717.9 Unspecified internal derangement of knee

Inclusion Diagnosis: Osteochondral Defect

ICD-9

717.7 Chondromalacia of patella
718.05 Articular cartilage disorder, pelvic region and thigh
718.09 Articular cartilage disorder, multiple sites
733.92 Chondromalacia

Inclusion Diagnosis: Traumatic Arthritis

ICD-9

716.10 Traumatic arthropathy, site unspecified
716.15 Traumatic arthropathy, pelvic region and thigh
716.16 Traumatic arthropathy, lower leg
716.18 Traumatic arthropathy, other specified sites
716.19 Traumatic arthropathy, multiple sites

Inclusion Diagnosis: Other Arthropathy

ICD-9

716.50 Unspecified polyarthropathy, site unspecified
716.55 Unspecified polyarthropathy, pelvic region and thigh
716.56 Unspecified polyarthropathy, lower leg
716.58 Unspecified polyarthropathy, other specified sites
716.59 Unspecified polyarthropathy, multiple sites
716.60 Unspecified monoarthritis, site unspecified
716.65 Unspecified monoarthritis, pelvic region and thigh
716.66 Unspecified monoarthritis, lower leg
716.68 Unspecified monoarthritis, other specified sites
716.69 Unspecified monoarthritis, multiple sites
716.90 Arthropathy, unspecified, site unspecified
716.95 Arthropathy, unspecified, pelvic region and thigh
716.96 Arthropathy, unspecified, lower leg
716.98 Arthropathy, unspecified, other specified sites
716.99 Arthropathy, unspecified, multiple sites
718.80 Other joint derangement, site unspecified
718.85 Other joint derangement, pelvic region and thigh
718.86 Other joint derangement, lower leg
718.88 Other joint derangement, other specified sites
718.89 Other joint derangement, multiple sites
718.90 Unspecified derangement of joint, site unspecified
718.95 Unspecified derangement of joint, pelvic region and thigh
718.96 Unspecified derangement of joint, lower leg
718.98 Unspecified derangement of joint, other specified sites
718.99 Unspecified derangement of joint, multiple sites
719.80 Other specified disorders of joint, site unspecified
719.85 Other specified disorders of joint, pelvic region and thigh

719.86 Other specified disorders of joint, lower leg
719.88 Other specified disorders of joint, other specified sites
719.89 Other specified disorders of joint, multiple sites
719.90 Unspecified disorder of joint, site unspecified
719.95 Unspecified disorder of joint, pelvic region and thigh
719.96 Unspecified disorder of joint, lower leg
719.98 Unspecified disorder of joint, other specified sites
719.99 Unspecified disorder of joint, multiple sites

Exclusion Procedures: Prior or Index Admission

CPT

27125 Hemiarthroplasty, hip, partial
27130 Arthroplasty, acetabular and proximal femoral prosthetic replacement
27132 Revision of previous hip surgery or total hip arthroplasty
27134 Revision of total hip arthroplasty; both components
27137 Revision of total hip arthroplasty; acetabular component only
27138 Revision of total hip arthroplasty; femoral component only
27442 Arthroplasty, knee, condyle or plateau
27443 Arthroplasty, knee, condyle or plateau; with debridement and partial synovectomy
27445 Arthroplasty, knee, hinge prosthesis (Walldius)
27446 Arthroplasty, knee, condyle and plateau; medial OR lateral compartment
27447 Arthroplasty, knee, condyle and plateau; medial AND lateral compartments with or without patellar resurfacing (total knee arthroplasty)
27486 Revision of total knee arthroplasty, with or without allograft; 1 component
27487 Revision of total knee arthroplasty, with or without allograft; femoral and entire tibial component
27488 Removal of prosthesis, including total knee prosthesis, methyl methacrylate with or without insertion of spacer

ICD-9

00.70 Revision of hip replacement, both acetabular and femoral components
00.71 Revision of hip replacement, acetabular component
00.72 Revision of hip replacement, femoral component
00.73 Revision of hip replacement, acetabular liner and/or femoral head only
00.74 Hip replacement bearing surface, metal on polyethylene
00.75 Hip replacement bearing surface, metal-on-metal
00.76 Hip replacement bearing surface, ceramic-on-ceramic
00.77 Hip replacement bearing surface, ceramic-on-polyethylene
00.80 Revision of knee replacement, total (all components)
00.81 Revision of knee replacement, tibial component
00.82 Revision of knee replacement, femoral component
00.83 Revision of knee replacement, patellar component
00.84 Revision of knee replacement, tibial insert (liner)
79.35 Open reduction of fracture with internal fixation
81.51 Total hip replacement
81.52 Partial hip replacement
81.53 Revision of hip replacement
81.54 Knee replacement: unicompartmental, bicompartmental, tricompartmental
81.55 Revision of knee replacement

Exclusion Diagnoses: Prior or Index Admission

ICD-9

138 Late effect of acute poliomyelitis
170.6 Malignant neoplasm of pelvic bones, sacrum, and coccyx
170.7 Malignant neoplasm of long bones of lower limb
170.8 Malignant neoplasm of short bones of lower limb
170.9 Malignant neoplasm of bone and articular cartilage, site unspecified
171.3 Malignant neoplasm of connective and other soft tissue of lowerlimb, including hip
171.8 Malignant neoplasm of connective and other soft tissue, other specified sites
171.9 Malignant neoplasm of connective and other soft tissue, site unspecified
173.7 Other specified malignant neoplasm of skin of lower limb, including hip
195.5 Malignant neoplasm of lower limb, site of origin undetermined
195.8 Malignant neoplasm of other specified sites, site of origin undetermined
196.5 Secondary and unspecified malignant neoplasm of lymph nodes of inguinal region and lower limbs
196.8 Secondary and unspecified malignant neoplasm of lymph nodes of multiple sites
196.9 Secondary and unspecified malignant neoplasm of lymph nodes, site unspecified
198.5 Secondary malignant neoplasm of bone and bone marrow
203.00 Multiple myeloma, without mention of remission
203.01 Multiple myeloma, in remission
203.02 Multiple myeloma, in relapse
203.10 Plasma cell leukemia, without mention of remission
203.11 Plasma cell leukemia, in remission
203.12 Plasma cell leukemia, in relapse
203.80 Other immunoproliferative neoplasms, without mention of remission
203.81 Other immunoproliferative neoplasms, in remission
203.82 Other immunoproliferative neoplasms, in relapse
213.7 Benign neoplasm of long bones of lower limb
238.0 Neoplasm of uncertain behavior of bone and articular cartilage
268.0 Rickets, active
268.1 Rickets, late effect
277.5 Mucopolysaccharidosis
315.8 Other specified delays in development
315.9 Unspecified delay in development
318.0 Moderate intellectual disabilities
318.1 Severe intellectual disabilities
318.2 Profound intellectual disabilities
319 Unspecified intellectual disabilities
334.1 Hereditary spastic paraplegia
343.0 Congenital diplegia
343.1 Congenital hemiplegia
343.2 Congenital quadriplegia
343.3 Congenital monoplegia
343.4 Infantile hemiplegia
343.8 Other specified infantile cerebral palsy
343.9 Infantile cerebral palsy, unspecified
344.1 Paraplegia
344.01 Quadriplegia, C1-C4, complete
682.6 Cellulitis and abscess of leg, except foot
707.0 Pressure ulcer
707.03 Pressure ulcer, lower back
707.04 Pressure ulcer, hip
707.05 Pressure ulcer, buttock
707.09 Pressure ulcer, other site
710.0 SLE

710.2 Sicca syndrome
711.00 Pyogenic arthritis, site unspecified
711.05 Pyogenic arthritis, pelvic region and thigh
711.06 Pyogenic arthritis, lower leg
711.07 Pyogenic arthritis, ankle and foot
711.08 Pyogenic arthritis, other specified sites
711.09 Pyogenic arthritis, multiple sites
711.10 Reiter arthritis, site unspecified
711.15 Reiter arthritis, pelvic region and thigh
711.16 Reiter arthritis, lower leg
711.17 Reiter arthritis, ankle and foot
711.18 Reiter arthritis, other specified sites
711.19 Reiter arthritis, multiple sites
711.20 Behcet arthritis, site unspecified
711.25 Behcet arthritis, pelvic region and thigh
711.26 Behcet arthritis, lower leg
711.27 Behcet arthritis, ankle and foot
711.28 Behcet arthritis, other specified sites
711.29 Behcet arthritis, multiple sites
711.30 Postdysenteric arthropathy, site unspecified
711.35 Postdysenteric arthropathy, pelvic region and thigh
711.36 Postdysenteric arthropathy, lower leg
711.37 Postdysenteric arthropathy, ankle and foot
711.38 Postdysenteric arthropathy, other specified sites
711.39 Postdysenteric arthropathy, multiple sites
711.40 Other bacterial arthropathy, site unspecified
711.45 Other bacterial arthropathy, pelvic region and thigh
711.46 Other bacterial arthropathy, lower leg
711.47 Other bacterial arthropathy, ankle and foot
711.48 Other bacterial arthropathy, other specified sites
711.49 Other bacterial arthropathy, multiple sites
711.50 Other viral arthropathy, site unspecified
711.55 Other viral arthropathy, pelvic region and thigh
711.56 Other viral arthropathy, lower leg
711.57 Other viral arthropathy, ankle and foot
711.58 Other viral arthropathy, other specified sites
711.59 Other viral arthropathy, multiple sites
711.60 Arthropathy associated with mycoses, site unspecified
711.65 Arthropathy associated with mycoses, pelvic region and thigh
711.66 Arthropathy associated with mycoses, lower leg
711.67 Arthropathy associated with mycoses, ankle and foot
711.68 Arthropathy associated with mycoses, other specified sites
711.69 Arthropathy associated with mycoses, multiple sites
711.70 Arthropathy associated with helminthiasis, site unspecified
711.75 Arthropathy associated with helminthiasis, pelvic region and thigh
711.76 Arthropathy associated with helminthiasis, lower leg
711.77 Arthropathy associated with helminthiasis, ankle and foot
711.78 Arthropathy associated with helminthiasis, other specified sites
711.79 Arthropathy associated with helminthiasis, multiple sites
711.80 Other infectious and parasitic arthropathy, site unspecified
711.85 Other infectious and parasitic arthropathy, pelvic region and thigh
711.86 Other infectious and parasitic arthropathy, lower leg
711.87 Other infectious and parasitic arthropathy, ankle and foot
711.88 Other infectious and parasitic arthropathy, other specified sites
711.89 Other infectious and parasitic arthropathy, multiple sites
711.90 Unspecified infective arthritis, site unspecified
711.95 Unspecified infective arthritis, pelvic region and thigh
711.96 Unspecified infective arthritis, lower leg
711.97 Unspecified infective arthritis, ankle and foot
711.98 Unspecified infective arthritis, other specified sites
711.99 Unspecified infective arthritis, multiple sites
714.0 Rheumatoid arthritis
714.1 Felty syndrome
714.2 Other rheumatoid arthritis with visceral or systemic involvement
714.30 Polyarticular juvenile rheumatoid arthritis, chronic or unspecified
714.31 Polyarticular juvenile rheumatoid arthritis, acute
714.32 Pauciarticular juvenile rheumatoid arthritis
714.33 Monoarticular juvenile rheumatoid arthritis
714.4 Chronic postrheumatic arthropathy
714.89 Other specified inflammatory polyarthropathies
714.9 Unspecified inflammatory polyarthropathy
718.20 Pathological dislocation of joint, site unspecified
718.25 Pathological dislocation of joint, pelvic region and thigh
718.26 Pathological dislocation of joint, lower leg
718.27 Pathological dislocation of joint, ankle and foot
718.28 Pathological dislocation of joint, other specified sites
718.29 Pathological dislocation of joint, multiple sites
718.30 Recurrent dislocation of joint, site unspecified
718.35 Recurrent dislocation of joint, pelvic region and thigh
718.36 Recurrent dislocation of joint, lower leg
718.37 Recurrent dislocation of joint, ankle and foot
718.38 Recurrent dislocation of joint, other specified sites
718.39 Recurrent dislocation of joint, multiple sites
718.75 Developmental dislocation of joint, pelvic region and thigh
718.76 Developmental dislocation of joint, lower leg
720.0 Ankylosing spondylitis
728.0 Infective myositis
728.86 Necrotizing fasciitis
730.00 Acute osteomyelitis, site unspecified
730.05 Acute osteomyelitis, pelvic region and thigh
730.06 Acute osteomyelitis, lower leg
730.07 Acute osteomyelitis, ankle and foot
730.08 Acute osteomyelitis, other specified sites
730.09 Acute osteomyelitis, multiple sites
730.10 Chronic osteomyelitis, site unspecified
730.15 Chronic osteomyelitis, pelvic region and thigh
730.16 Chronic osteomyelitis, lower leg
730.17 Chronic osteomyelitis, ankle and foot
730.18 Chronic osteomyelitis, other specified sites
730.19 Chronic osteomyelitis, multiple sites
730.20 Unspecified osteomyelitis, site unspecified
730.25 Unspecified osteomyelitis, pelvic region and thigh
730.26 Unspecified osteomyelitis, lower leg
730.27 Unspecified osteomyelitis, ankle and foot
730.28 Unspecified osteomyelitis, other specified sites
730.29 Unspecified osteomyelitis, multiple sites
730.30 Periostitis, site unspecified
730.35 Periostitis, pelvic region and thigh
730.36 Periostitis, lower leg
730.37 Periostitis, ankle and foot
730.38 Periostitis, other specified sites
730.39 Periostitis, multiple sites
730.70 Osteopathy from poliomyelitis, site unspecified
730.75 Osteopathy from poliomyelitis, pelvic region and thigh

730.76 Osteopathy from poliomyelitis, lower leg
730.77 Osteopathy from poliomyelitis, ankle and foot
730.78 Osteopathy from poliomyelitis, other specified sites
730.79 Osteopathy from poliomyelitis, multiple sites
730.80 Other infections involving bone, site unspecified
730.85 Other infections involving bone, pelvic region and thigh
730.86 Other infections involving bone, lower leg
730.87 Other infections involving bone, ankle and foot
730.88 Other infections involving bone, other specified sites
730.89 Other infections involving bone, multiple sites
730.90 Unspecified infection of bone, site unspecified
730.95 Unspecified infection of bone, pelvic region and thigh
730.96 Unspecified infection of bone, lower leg
730.97 Unspecified infection of bone, ankle and foot
730.98 Unspecified infection of bone, other specified sites
730.99 Unspecified infection of bone, multiple sites
731.0 Osteitis deformans without mention of bone tumor (Paget)
731.1 Osteitis deformans in other diseases
732.1 Juvenile osteochondrosis of hip and pelvis
732.2 Nontraumatic slipped upper femoral epiphysis
732.4 Juvenile osteochondrosis of lower extremity, excluding foot
732.6 Other juvenile osteochondrosis
732.7 Osteochondritis dissecans
732.8 Other specified forms of osteochondropathy
732.9 Unspecified osteochondropathy
733.10 Pathological fracture, unspecified site
733.14 Pathological fracture, neck of femur
733.15 Pathological fracture, other part of femur
733.16 Pathological fracture, tibia or fibula
733.19 Pathological fracture of other specified site
733.20 Cyst of bone (localized), unspecified
733.21 Solitary bone cyst
733.22 Aneurysmal bone cyst
733.29 Other bone cyst
733.42 Aseptic necrosis of medial femoral condyle
733.81 Malunion of fracture
733.82 Nonunion of fracture
741.00 Spina bifida with hydrocephalus, unspecified region
741.01 Spina bifida with hydrocephalus, cervical region
741.02 Spina bifida with hydrocephalus, dorsal (thoracic) region
741.03 Spina bifida with hydrocephalus, lumbar region
741.90 Spina bifida without hydrocephalus, unspecified region
741.91 Spina bifida without hydrocephalus, cervical region
741.92 Spina bifida without hydrocephalus, thoracic region
741.93 Spina bifida without hydrocephalus, lumbar region
754.30 Congenital dislocation of hip, unilateral
754.31 Congenital dislocation of hip, bilateral
754.32 Congenital subluxation of hip, unilateral
754.33 Congenital subluxation of hip, bilateral
754.34 Congenital subluxation of 1 hip with subluxation of other hip
754.40 Genu recurvatum
754.41 Congenital dislocation of knee (with genu recurvatum)
754.42 Congenital bowing of femur
754.43 Congenital bowing of tibia and fibula
754.44 Congenital bowing of unspecified long bones of leg
755.30 Unspecified reduction deformity of lower limb
755.31 Transverse deficiency of lower limb
755.32 Longitudinal deficiency of lower limb, not elsewhere classified
755.33 Longitudinal deficiency of lower limb, combined
755.34 Longitudinal deficiency of lower limb, femoral
755.35 Longitudinal deficiency of lower limb, tibiofibular
755.36 Longitudinal deficiency of lower limb, tibial
755.37 Longitudinal deficiency of lower limb, fibular
755.55 Acrocephalosyndactyly
755.60 Unspecified anomaly of lower limb
755.61 Coxa valga, congenital
755.62 Coxa vara, congenital
755.63 Other congenital deformity of hip (joint)
755.64 Congenital deformity of knee (joint)
755.69 Other anomalies of lower limb, including pelvic girdle
756.4 Chondrodystrophy
756.50 Congenital osteodystrophy, unspecified
756.51 Osteogenesis imperfecta
756.52 Osteopetrosis
756.53 Osteopoikilosis
756.54 Polyostotic fibrous dysplasia of bone
756.55 Chondroectodermal dysplasia
756.56 Multiple epiphyseal dysplasia
756.59 Other osteodystrophies
756.9 Other and unspecified anomalies of musculoskeletal system
783.40 Lack of normal physiological development in childhood
808.0 Closed fracture of acetabulum
808.1 Open fracture of acetabulum
808.2 Closed fracture of pubis
808.3 Open fracture of pubis
808.41 Closed fracture of ilium
808.42 Closed fracture of ischium
808.43 Multiple closed pelvic fractures with disruption of pelvic circle
808.44 Multiple closed pelvic fractures without disruption of pelvic circle
808.49 Closed fracture of other specified part of pelvis
808.51 Open fracture of ilium
808.52 Open fracture of ischium
808.53 Multiple open pelvic fractures with disruption of pelvic girdle
808.54 Multiple open pelvic fractures without disruption of pelvic girdle
808.59 Open fracture of other specified part of pelvis
808.8 Closed unspecified fracture of pelvis
808.9 Open unspecified fracture of pelvis
820.00 Closed fracture of intracapsular section of neck of femur, unspecified
820.01 Closed fracture of epiphysis (separation) (upper) of neck of femur
820.02 Closed fracture of midcervical section of neck of femur
820.03 Closed fracture of base of neck of femur
820.09 Other closed transcervical fracture of neck of femur
820.10 Open fracture of intracapsular section of neck of femur, unspecified
820.11 Open fracture of epiphysis (separation) (upper) of neck of femur
820.12 Open fracture of midcervical section of neck of femur
820.13 Open fracture of base of neck of femur
820.19 Other open transcervical fracture of neck of femur
820.20 Closed fracture of trochanteric section of neck of femur, unspecified
820.21 Closed fracture of intertrochanteric section of neckof femur
820.22 Closed fracture of subtrochanteric section of neck of femur
820.30 Open fracture of trochanteric section of neck of femur, unspecified
820.31 Open fracture of intertrochanteric section of neck of femur
820.32 Open fracture of subtrochanteric section of neck of femur
820.8 Closed fracture of unspecified part of neck of femur

820.9 Open fracture of unspecified part of neck of femur
821.00 Closed fracture of unspecified part of femur
821.01 Closed fracture of shaft of femur
821.10 Open fracture of unspecified part of femur
821.11 Open fracture of shaft of femur
821.20 Closed fracture of lower end of femur
821.21 Closed fracture of condyle, femoral
821.22 Closed fracture of epiphysis, lower (separation) of femur
821.23 Closed supracondylar fracture of femur
821.29 Other closed fracture of lower end of femur
821.3 Open fracture of lower end of femur, unspecified
821.31 Open fracture of condyle, femoral
821.32 Open fracture of epiphysis, lower (separation) of femur
821.33 Open supracondylar fracture of femur
821.39 Other open fracture of lower end of femur
823.00 Closed fracture of upper end of tibia alone
823.02 Closed fracture of upper end of fibula with tibia
823.10 Open fracture of upper end of tibia alone
823.12 Open fracture of upper end of fibula with tibia
823.20 Closed fracture of shaft of tibia alone
823.22 Closed fracture of shaft of fibula with tibia
823.30 Open fracture of shaft of tibia alone
823.32 Open fracture of shaft of fibula with tibia
823.40 Torus fracture, tibia alone
823.42 Torus fracture, fibula with tibia
823.80 Closed fracture of unspecified part of tibia alone
823.82 Closed fracture of unspecified part of fibula with tibia
823.90 Open fracture of unspecified part of tibia alone
823.92 Open fracture of unspecified part of fibula with tibia
827.0 Other, multiple and ill-defined fractures of lower limb, closed
827.1 Other, multiple and ill-defined fractures of lower limb, open
828.0 Closed multiple fractures involving both lower limbs, lower with upper limb, and lower limb(s) with rib(s) and sternum
828.1 Open multiple fractures involving both lower limbs, lower with upper limb, and lower limb(s) with rib(s) and sternum
835.00 Closed dislocation of hip, unspecified site
835.01 Closed posterior dislocation of hip
835.02 Closed obturator dislocation of hip
835.03 Other closed anterior dislocation of hip
835.10 Open dislocation of hip, unspecified site
835.11 Open posterior dislocation of hip
835.12 Open obturator dislocation of hip
835.13 Other open anterior dislocation of hip
836.0 Tear of medial cartilage or meniscus of knee with dislocation, current
836.1 Tear of lateral cartilage or meniscus of knee with dislocation, current
836.2 Other tear of cartilage or meniscus of knee with dislocation, current
836.3 Dislocation of patella, closed
836.4 Dislocation of patella, open
836.50 Dislocation of knee, unspecified, closed
836.51 Anterior dislocation of tibia, proximal end, closed
836.52 Posterior dislocation of tibia, proximal end, closed
836.53 Medial dislocation of tibia, proximal end, closed
836.54 Lateral dislocation of tibia, proximal end, closed
836.59 Other dislocation of knee, closed
836.60 Dislocation of knee, unspecified, open
836.61 Anterior dislocation of tibia, proximal end, open
836.62 Posterior dislocation of tibia, proximal end, open
836.63 Medial dislocation of tibia, proximal end, open
836.64 Lateral dislocation of tibia, proximal end, open
836.69 Other dislocation of knee, open
905.3 Late effect of fracture of neck of femur
905.4 Late effect of fracture of lower extremities
996.4 Mechanical complication of internal orthopaedic device/implant/graft
996.40 Unspecified mechanical complication of internal orthopaedic device/implant/graft
996.41 Mechanical loosening of prosthetic joint
996.42 Dislocation of prosthetic joint
996.43 Broken prosthetic joint implant
996.44 Periprosthetic fracture
996.45 Periprosthetic osteolysis
996.46 Articular bearing surface wear of prosthetic joint
996.47 Other mechanical complication of prosthetic joint implant
996.49 Other mechanical complication of other internal orthopaedic device/implant/graft
996.66 Infection and inflammatory reaction due to internal joint prosthesis
996.67 Infection and inflammatory reaction due to other internal orthopaedic device/implant/graft
996.77 Other complications due to internal joint prosthesis
996.78 Other complications due to other internal orthopaedic device/implant/graft
V43.64 Hip joint replacement
V43.65 Knee joint replacement
V45.4 Arthrodesis status
V54.01 Encounter for removal of internal fixation device
V54.09 Other aftercare involving internal fixation device
V54.81 Aftercare after joint replacement
V54.82 Aftercare after explantation of joint prosthesis

Outcome Procedure: Knee Arthroplasty

CPT

27442 Arthroplasty, knee, condyle or plateau
27443 Arthroplasty, knee, condyle or plateau; with debridement and partial synovectomy
27445 Arthroplasty, knee, hinge prosthesis (Walldius)
27446 Arthroplasty, knee, condyle and plateau; medial OR lateral compartment
27447 Arthroplasty, knee, condyle and plateau; medial AND lateral compartments with or without patella resurfacing (total knee arthroplasty)
27486 Revision of total knee arthroplasty, with or without allograft; 1 component
27487 Revision of total knee arthroplasty, with or without allograft; femoral and entire tibial components

ICD-9

00.80 Revision of knee replacement, total (all components)
00.82 Revision of knee replacement, tibial component
81.54 Knee replacement: unicompartmental, bicompartmental, tricompartmental
81.55 Revision of knee replacement

[a]ACL, anterior cruciate ligament; LCL, lateral collateral ligament; MCL, medial collateral ligament; PCL, posterior cruciate ligament; SLE, systemic lupus erythematosus.