Opening- and Closing-Wedge Distal Femoral Osteotomy

A Systematic Review of Outcomes for Isolated Lateral Compartment Osteoarthritis

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Background: Lateral compartment osteoarthritis of the knee can be a challenging pathology in the younger, active population due to limited treatment options and high patient expectations. Distal femoral osteotomy (DFO) has been reported to be a potential treatment option.

Purpose: To perform a systematic review on the survival, outcomes, and complications of DFO for treatment of genu valgum with concomitant lateral compartment osteoarthritis of the knee.

Study Design: Systematic review; Level of evidence, 4.

Methods: A systematic review of the literature was performed using the Cochrane Database of Systematic Reviews, the Cochrane Central Registry of Controlled Trials, PubMed, and MEDLINE from 1980 to present. Inclusion criteria were as follows: outcomes of opening- and closing-wedge DFOs performed for treatment of genu valgum with concomitant lateral compartment osteoarthritis of the knee, English language, minimum 2-year follow-up, and human studies. Data abstracted from the selected studies included type of osteotomy (opening vs closing), survival rate, patient-reported and radiographic outcomes, and complications.

Results: Fourteen studies met the inclusion criteria and were considered for the review. A total of 9 closing-wedge and 5 opening-wedge DFO studies were included. All were retrospective studies and reported good to excellent patient-reported outcomes after DFO. Survival decreased with increasing time from surgery, with 1 study reporting a 100% survival rate at 6.5 years, compared with 21.5% at 20 years in another study. A low rate of complications was reported throughout the review.

Conclusion: Highly heterogeneous literature exists for both opening- and closing-wedge DFOs for the treatment of isolated lateral compartment osteoarthritis with valgus malalignment. A mean survival rate of 80% at 10-year follow-up was reported, supporting that this procedure can be a viable treatment option to delay or reduce the need for joint arthroplasty. A low complication rate was observed, with symptomatic hardware being the most prevalent postoperative complication.

Keywords: distal femoral osteotomy; lateral compartment osteoarthritis; valgus alignment; genu valgum; opening wedge; closing wedge

Valgus malalignment of the knee in young, active patients is a challenging entity because it may lead to the early development or progression of lateral compartment osteoarthritis.[8] While knee varus deformity is more common, valgus malalignment can result after trauma, as part of metabolic disease, after lateral meniscectomy, or from other conditions affecting growth plate morphology.[11]

Valgus knee anatomic alignment beyond physiologic valgus (5°-8°) leads to excessive loading of the lateral compartment, which can increase the risk for progression of osteoarthritis and can theoretically place the medial knee structures at risk for chronic attenuation.[8] Furthermore, it has been reported that the amount of wear leading to cartilaginous breakdown within the joint correlates with

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the degree of valgus deformity.[20] Deviation from the normal lower limb axis can result in alterations in gait, as well as malfunctioning or imbalance of the knee ligamentous complexes.

In severe cases of valgus deformity greater than 12°, the distal femur is the preferred site of osteotomy because correction through the proximal tibia often fails to correct the orientation of the joint line and can result in lateral subluxation of the tibia.[9] Of note, distal femoral osteotomy (DFO) should only be used to correct malalignment in extension and not in flexion. This finding of lateral tibial subluxation was clinically reinforced by Coventry,[3] who reported poor results after proximal tibial osteotomy in patients with valgus deformity. For this reason, varus-producing DFOs are widely accepted to treat lateral compartment overload or isolated osteoarthritis. However, the choice to utilize an opening- or closing-wedge technique is less uniform.

Whether an opening- or a closing-wedge osteotomy yields superior outcomes remains to be determined, as current literature supports both procedures. The available literature regarding DFO is limited and heterogeneous with respect to indications, surgical technique, timing of surgery, rehabilitation, and outcomes. The purpose of this study was to systematically review the literature on opening- and closing-wedge DFO with regard to survival rate (defined as the rate of conversion to total knee replacement). Furthermore, this study seeks to compare patient-reported and radiographic/alignment outcomes for the treatment of valgus deformity of the knee with lateral compartment osteoarthritis and complication rates for an opening- or closing-wedge DFO procedure. Our hypothesis was that DFOs had good reported outcomes with a high survival rate up to 10 years postoperatively.

METHODS

Article Identification and Selection

This study was conducted in accordance with the 2009 Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement.[16] A systematic review of the literature regarding the existing evidence for outcomes of opening- and closing-wedge DFOs was performed using the Cochrane Database of Systematic Reviews, the Cochrane Central Register of Controlled Trials, PubMed (1980-2014), and MEDLINE (1980-2014). The queries were performed in November 2015.

The literature search strategy included the following: Search 1: distal [All Fields] AND ("femur"[MeSH Terms] OR "femur"[All Fields] OR "femoral"[All Fields]) AND ("osteotomy"[MeSH Terms] OR "osteotomy"[All Fields]) AND valgus[All Fields] and search 2: distal [All Fields] AND ("femur"[MeSH Terms] OR "femur"[All Fields] OR "femoral"[All Fields]) AND ("osteotomy"[MeSH Terms] OR "osteotomy"[All Fields]) AND valgus[All Fields] AND (opening[All Fields] OR closing [All Fields]) AND wedge[All Fields].

Inclusion criteria were as follows: studies including outcomes of opening- and/or closing-wedge DFOs performed for the treatment of genu valgum with concomitant lateral compartment osteoarthritis of the knee, written in the English language, with a minimum of 2-year follow-up, and evaluating only human subjects. We excluded cadaveric studies, animal studies, basic science articles, editorial articles, surgical technique descriptions, surveys, DFO used to treat conditions other than malalignment and osteoarthritis (such as patellar dislocation), the use of external fixator as the predominant mode of fixation, or casting to maintain the reduction. We also excluded publications that evaluated patients with posttraumatic deformities.

Three investigators (J.C., J.J.M., D.J.L.) independently reviewed the abstracts from all identified articles. Full-text articles were obtained for review, if necessary, to allow further assessment of inclusion and exclusion criteria. Additionally, all references from the included studies were reviewed and reconciled to verify that no relevant articles were missing from the systematic review.

Data Collection

The level of evidence of the studies was assigned according to the classification as specified by Wright et al.[24] Using the included studies, reported survival rates were collected for our primary endpoint. Additionally, our secondary endpoints were preoperative and postoperative patient-reported outcomes and complication rates for an opening- or closing-wedge DFO procedure. Patient demographics, follow-up, and objective and subjective outcomes were extracted and recorded. For continuous variables (eg, age, timing, follow-up, outcome scores), the mean and range were collected if reported. Data were recorded into a custom Excel spreadsheet (Microsoft Corp) using a modified information extraction table.[10]

RESULTS

Study Selection

The process for study selection is presented in Figure 1. Literature searches of the PubMed database along with careful examination of reference lists and citation searches revealed a total of 696 individual titles and abstracts, including duplicates. After initial screening and removal of duplicates, 658 studies were eliminated based on the inclusion and exclusion criteria noted above, leaving a total of 38 articles for full-text review. After a thorough review of these articles and their citations along with a repeated search of the literature, a total of 9 closing-wedge and 5 opening-wedge DFO clinical studies were included in the systematic review. All included articles had an evidence level of 4.

Closing-Wedge Distal Femoral Osteotomy

Indications. All patients included in the studies were indicated for surgery because of painful isolated lateral compartment osteoarthritis and associated valgus deformity.

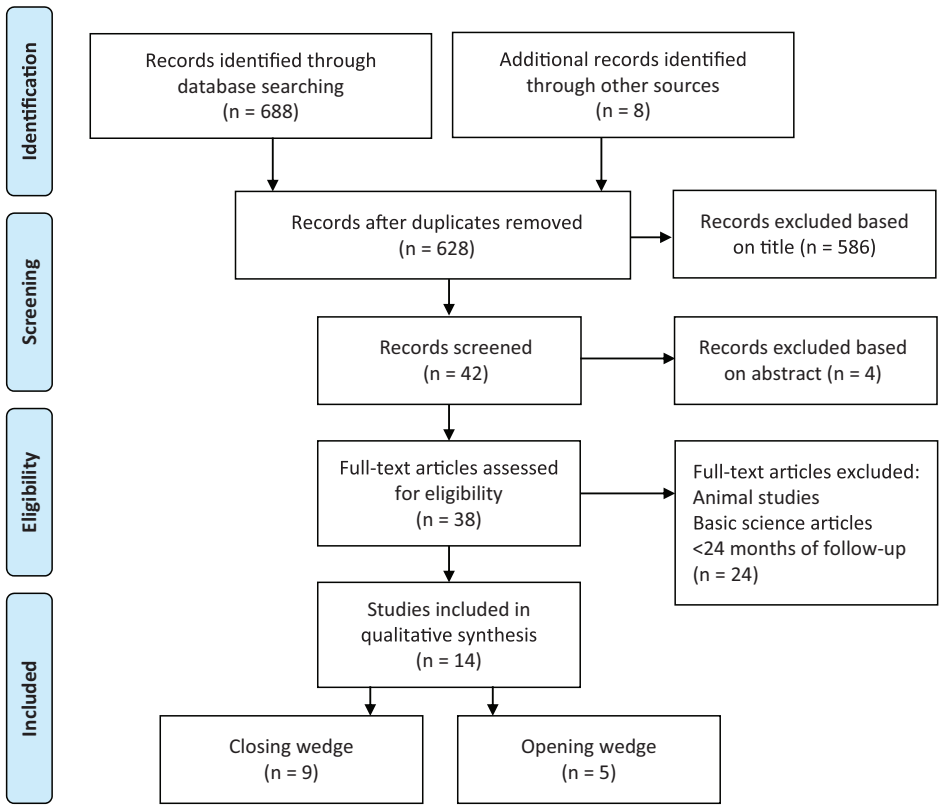

Figure 1. Flowchart showing selection process of systematic review.

However, preoperative patient selection criteria differed among the included studies (Table 1).

Demographics. All studies were performed retrospectively and included a total of 236 patients (248 knees) with a mean age of 48.9 years (range, 40-56 years). The mean follow-up was 8 years (range, 2.5-15.1 years). None of these studies stratified their patients according to Kellgren-Lawrence or Ahlbäck classification (Table 2). Regarding rehabilitation protocols, all closing-wedge osteotomy studies utilized a partial weightbearing protocol for 6 weeks. Healy et al[11] restricted weightbearing to toe-touch for the first 4 weeks (Table 3).

Survival Rate. Closing-wedge DFO survival rates varied from 83%[11] to 92%[15] at 4 years follow-up to 21.5% at 20-year follow-up. Survival rates after 10 years varied from 64% to 89.9% reported in 4 studies.[1,6,21,23] Three studies[1,13,21] reported survival rates after 15 years ranging from 45% to 78.9%. Survival rates of the included studies are summarized in Table 3. Failure rates tended to increase with time, particularly in postoperative periods greater than 10 years.

Radiologic and Patient-Reported Outcomes. Five of the 9 studies reported preoperative valgus deformity, yielding a range from 11.6° to 18.2° anatomic alignment.[1,23] After closing-wedge correction, mean postoperative deformity was 1.2° to 2°.[1,11,23] One study[7] reported preoperative and postoperative valgus deformity as a percentage of the Mikulicz line intersection with the tibial plateau, defining greater than 60% intersection as genu valgum, and found pre- and postoperative values to be 77.3% and 42.6%, respectively.

Two of 9 studies[11,23] reported Hospital for Special Surgery (HSS) knee scores with mean preoperative scores of 46 and 65 and mean postoperative scores of 88 and 86, respectively. Two of 9 studies[13,21] reported Modified Knee Society Scores (MKSS) with mean preoperative scores of 36.1 and 36.8 and mean postoperative scores from 60.5 and 59, respectively. Overall, all patient-reported outcome scores improved postoperatively. The data are summarized in Table 4.

Safety. Five of the 9 closing-wedge DFO studies reported complications[6,7,11,14,15] ranging from 0%[14] to 73%[7]. The high percentage of adverse events reported by Forkel et al[7] were due to discomfort over the plate in 16 of 22 patients. Major complications included 2 pulmonary emboli,[6,15] which were both treated successfully with anticoagulation. Failure of fixation with need for revision surgery was reported in 2 patients.[6,15] One of these patients went on to have a satisfactory result,[15] while the other patient experienced a femur fracture proximal to the blade plate that required conversion to a total knee arthroplasty with a long stem femoral component.[6] Wound infections were reported in 2 patients.[6,15] Manipulation under anesthesia was required in 8 patients (6 in the study by Healy et al[11], 1 for McDermott et al,[15] and 1 for Finkelstein et al[6]). Nonunion was reported in 2 patients.[11]

TABLE 1
Inclusion Criteria[a]

Closing-wedge DFO	
Backstein et al[1] (2007)	All patients who underwent DFO for isolated lateral unicompartmental OA with valgus deformity between 1972 and 2002 were included.
Finkelstein et al[6] (1996)	All patients who underwent DFO for isolated lateral unicompartmental OA with valgus deformity between 1972 and 1985 were included.
Sternheim et al[21] (2011)	All patients within the timeframe were included. However, prerequisites for distal femoral varus osteotomy were a 90° range of motion in the knee, age <60 years for females and <65 for males, and physical and mental capability of a long rehabilitation process lasting up to 9 months.
Kosashvili et al[13] (2009)	Thirty-three consecutive knees that underwent DFO for isolated lateral unicompartmental OA with valgus deformity between January 1984 and January 1999 with a minimum follow-up of 10 years were included.
Forkel et al[7] (2013)	Twenty-three consecutive patients with symptomatic grade III to IV cartilage damage and valgus knee alignment were included. Prerequisites for undergoing the procedure included: intact medial cartilage and meniscus, desire of the patient to continue with sporting activity, and age <55 years. Radiological definition of genu valgum was an intersection of the Mikulicz line with the tibia plateau at >60%.
Wang and Hsu[23] (2005)	The indication DFO was a painful deformity of the knee associated with a valgus tibiofemoral angulation of ≥12° and narrowing of the lateral joint space. Contraindications included severe arthritis of the medial compartment of the knee, severe tricompartmental OA, and tibiofemoral subluxation.
McDermott et al[15] (1988)	Included patients had OA of the lateral compartment that was associated with a valgus deformity and a superolateral tilt to the joint line. They also had both clinical and radiographic deformity of the involved knee, a normal or minimally involved medial compartment, good vascular circulation, and flexion of the knee to ≥90°.
Healy et al[11] (1988)	Eighteen knees with varying forms of arthritis that had a primary indication for distal femoral varus osteotomy because of noted painful valgus deformity of the knee with narrowing of the lateral joint space.
Learmonth et al[14] (1990)	All patients who underwent DFO for isolated lateral unicompartmental OA with valgus deformity.
Opening-wedge DFO	
Das et al[4] (2007)	Indication for an opening-wedge osteotomy was mild to moderate lateral radiographic OA associated with genu valgum malalignment of >10° in a patient with a biological age of <65 years.
Dewilde et al[5] (1996)	Indication for DFO was the presence of isolated lateral femorotibial OA associated with an underlying mild to moderate valgus deformity in patients aged <55 years with an active lifestyle and normal stability and range of motion of the knee.
Jacobi et al[12] (2011)	All included patients had lateral unicompartmental OA with an associated valgus axis.
Thein et al[22] (2005)	Patients included in this study were aged <65 years with isolated OA of the lateral compartment, tibiofemoral angle >12° of valgus, knee flexion >90° and a flexion contracture of <10°, and without ligamentous instability. The indication for surgery was knee pain due to evident OA on examination and standing radiographs that was not responsive to nonoperative treatment for at least 1 year.
Zarrouk et al[25] (1988)	The inclusion criteria for this study were complete radiological workup, minimum 3 years of follow-up, and a single surgical technique (ie, only DFO was performed). All patients had a unilateral or bilateral symptomatic valgus knee.

[a]DFO, distal femoral osteotomy; OA, osteoarthritis.

Opening-Wedge Distal Femoral Osteotomy

Demographics. Five studies reported on a total of 71 patients with a mean age of 49.5 years (range, 46-55 years) treated with opening-wedge DFO for lateral compartment osteoarthritis. All included studies were performed retrospectively with a mean follow-up of 4.6 years (range, 2.8-6.5 years). The Kellgren-Lawrence (K-L) classification was utilized to stratify patients in 2 studies (mean, 1.76[5] and 2.3[22].), and the Ahlbäck classification was used in 1 study (mean, 2.75[25]) (Table 2). The opening-wedge group was more heterogeneous regarding rehabilitation protocol. Nonweightbearing was the most utilized protocol (for 4 weeks[5], 6 weeks,[22] and 3 months[25]). Das et al[4] utilized a partial weightbearing protocol (Table 3).

Survival Rate. Survival rate was reported to be between 82%[5] and 100%[22] at final follow-up (range, 6[4]-8 years[25]). Zarrouk et al[25] reported the longest follow-up (8 years) on 20 patients with a survival rate of 91%. Of the 75 knees, there were 4 patients (5%) who went on to receive a total knee replacement at time of final follow-up.[4,5] Survival rates are summarized in Table 3.

Radiologic and Patient-Reported Outcomes. Five studies reported on mean preoperative valgus deformity with a valgus deformity range of 5.3°[5] to 16°[4] of anatomic alignment. Postoperative alignment improved in all studies, ranging from 1.3°[5] varus to 5° valgus.[4] One study[4] reported the HSS score, which improved from 42 preoperatively to 64 postoperatively. Zarrouk et al[25] reported improvements in 3 scores (IKS, modified KSS, and Functional scores). Time to union was reported in 3 studies[12,22,25] and ranged from 3 to 6 months. The results are summarized in Table 4.

Safety. All 5 opening-wedge DFO studies reported complication rates.[4,5,12,22,25] Complication rates ranged from 0%[22] to 30%[4] depending on the author definition of complication. Symptomatic hardware was the most frequent reported adverse event when combining all complications

TABLE 2
Demographic Data of Included Studies[a]

Study (Year)	Level of Evidence	Study Design	Patients (Knees), n	Age, y	Follow-up, y	K-L or Ahlbäck Grade	Concurrent Procedures
Closing-wedge DFO							
Backstein et al[1] (2007)	4	Retrospective	36 (38)	44.1	10.25		0
Finkelstein et al[6] (1996)	4	Retrospective	20 (21)	56	11.08		0
Sternheim et al[21] (2011)	4	Retrospective	41 (45)	46.2	13.3		0
Kosashvili et al[13] (2009)	4	Retrospective	31 (33)	45.5	15.1		0
Forkel et al[7] (2013)	4	Retrospective	22 (22)	47	2.5		Microfracture (17 patients)
Wang and Hsu[23] (2005)	4	Retrospective	30 (30)	53	8.25		Lateral compartment subchondral drilling (30 patients), lateral release and patellofemoral subchondral drilling (6 patients), proximal patellar realignment (1 patient), distal patellar realignment (1 patient)
McDermott et al[15] (1988)	4	Retrospective	24 (24)	53	4		0
Healy et al[11] (1988)	4	Retrospective	21 (23)	56	4		0
Learmonth et al[14] (1990)	4	Retrospective	11 (12)	40	3.41		0
Total			236 (248)	48.98	7.99		55
Opening-wedge DFO							
Das et al[4] (2007)	4	Retrospective	12 (13)	55	2.83		0
Dewilde et al[5] (1996)	4	Retrospective	19 (19)	47	5.66	1.76	Autologous chondrocyte implantation (1 patient)
Jacobi et al[12] (2011)	4	Retrospective	14 (14)	46	3.75		0
Thein et al[22] (2005)	4	Retrospective	6 (7)	46.7	6.5	2.3	0
Zarrouk et al[25] (1988)	4	Retrospective	20 (22)	53	4.5	2.75[b]	0
Total			71 (75)	49.54	4.65		1

[a]DFO, distal femoral osteotomy; K-L, Kellgren-Lawrence.
[b]Ahlbäck classification.

from the opening-wedge studies. A delayed union was reported in 2 patients.[4,25] Dewilde et al[5] reported a fall in 1 patient at 2 months postoperatively sustaining a fracture and angulation of the osteotomy site. She was successfully revised using an Ilizarov frame but was considered as a failure in our survivorship analysis.[5] In contrast to the closing-wedge DFO studies, no patients required manipulation under anesthesia for postoperative stiffness.

DISCUSSION

The most important finding of this systematic review was that a limited and highly heterogeneous body of literature was found to exist for both opening- and closing-wedge DFOs for the treatment of isolated lateral compartment osteoarthritis with valgus malalignment. A mean survival rate of 65% to 90% at 10-year follow-up was reported for closing-wedge DFOs. However, mean survival rates decreased over time with 58% at 15 years and 21.5% at 20 years. Likewise, opening-wedge failure rates were comparable (84%-100%) between 6- and 8-year follow-up. Overall, low complication rates were observed, with hardware-related issues being the most prevalent.

Survival rates at a minimum 2 years after opening- and closing-wedge DFO were presented in 11 of 14 studies (7 closing wedge[1,6,11,13,15,21,23] and 4 opening wedge[4,5,22,25]). Survival rate was similar throughout all studies, noting a 64% to 90% (mean survival rate, 80%) survival rate at less than or equal to 10 years after surgery. However, if patients were followed longer than 10 years after surgery, survival rates diminished, with most studies revealing an average of 58% survivorship at 15 years[1,13] and 21.5% at 20 years.[21] Of note, the survival reporting from the closing-wedge group has considerably longer follow-up, making comparison difficult. However, the available data from the opening-wedge cohort are similar in reported numbers. Survival data are also limited in that they do not stratify failure rates based on age. For the purpose of patient selection and to help in decision-making, a more clearly defined age cutoff describing at which age patients begin to have decreased survivorship would be advantageous.

Age-corrected survival rates are pertinent because previous reports have noted decreased clinical outcomes for total knee arthroplasty (TKA) after DFO.[17] Although TKA has a high success rate in the older population, patients younger than 55 years have a 3- to 5-fold increase in risk of revision surgery.[19] TKA after closing-wedge DFO has also been reported to be more difficult to perform, as the deformity is shifted extra-articularly and as such, isolated intra-articular correction during TKA could result in varus positioning of the prosthesis or result in ligamentous instability, requiring the use of a constrained prosthesis.[17,18] While there are some reports noting good functional outcomes and similar technical demands compared with primary TKA,[2,6] it would still stand to reason that

TABLE 3
Objective Outcomes and Postoperative Management[a]

Study	Implant/ Gap Filling	Mean Preoperative Valgus	Mean Postoperative Axes	Time to Union	Immobilization	Weightbearing	Survival Rate	TKR	Complications
Closing-wedge DFO									
Backstein et al[2]	90° offset DCBP	TF 11.6 (range, 4-15)	1.2 varus (0°-5°)	N/R	N/R	PWB 6-8 wk	82%: 10 y 45%: 15 y	8	N/R
Finkelstein et al[6]	90° offset DCBP	N/R	N/R	N/R	2 wk cast	PWB 6-8 wk if consolidation	64%: 10 y	7	N/R
Sternheim et al[21]	90° offset DCBP	N/R	N/R	N/R	N/R	6-8 wk postop if consolidation	89.9%: 10 y 78.9%: 15 y 21.5%: 20 y	—	N/R
Kosashvili et al[13]	90° offset DCBP	N/R	N/R	N/R	N/R	6-8 wk postop if consolidation	51.5%: 15y	15	N/R
Forkel et al[7]	Angle stable locking plate	77.30%	42.60%	N/R	N/R	PWB 6 wk			16/22 (73%) plate discomfort
Wang and Hsu[23]	90° offset DCBP	TF 18.2 (range, 12-27)	1.2 valgus (6 varus to 10 valgus)	4.7 mo (range, 3-9)	Hinged brace - healing	PWB 6-8 wk, FWB after 3 mo	87%: 10 y	3	N/R
McDermott et al[15]	90° offset DCBP			N/R	N/R	PWB 6 wk if consolidation	92%: 4 y	1	4/24 (17%) hardware failure, stiffness, wound infection, PE
Healy et al[11]	90° offset DCBP	TF 18 (range, 10-33)	2 valgus (7 varus to 6 valgus)	N/R	Brace if fixation is questionable	Toe-touch 6 wk, FWB at 12 wk	83%: 4 y	2	2 nonunions, 1 traumatic fracture, 1 stiffness
Learmonth et al[14]	90° offset AO plate		0° (9 patients), 2° valgus (2 patients), 1.5° valgus (1 patient)	N/R	N/R				None
Opening-wedge DFO									
Das et al[4]	Puddu plate (Arthrex)/ allograft	TF 16	5	N/R	8 wk	PWB with crutches	84%: 6 y	2	1 delayed union, 3 persistent pain
Dewilde et al[5]	Puddu plate/ calcium phosphate cement	TF 5.3	1.3 varus	N/R	8 wk	NWB 4 wk	82%: 7 y	2	1 osteotomy fracture after fall
Jacobi et al[12]	Tomofix plate cortical iliac crest autograft 7/14	N/R	Correction 5.8°	86% at 6 mo	N/R	—	N/R	—	3 plate discomfort
Thein et al[22]	Puddu plate/ tricortical iliac crest allograft	TF 13.5 ± 4.1	1.6 ± 2.1	3 mo	HKB	NWB 6 wk	100%: 6.5 y	0	None
Zarrouk et al[25]	Blade plate bent to 95°/no grafting	TF 14.5 (range, 8-18)	1.5 (range, –3 to 6)	3.5 mo	N/R	NWB 3 mo	91%: 8 y	0	1 postop hematoma, 1 delayed union

[a]AO, Arbeitsgemeinschaft für Osteosynthesefragen (Association for the Study of Internal Fixation); DCBP, dynamic compression blade plate; DFO, distal femoral osteotomy; FWB, full weightbearing; HKB, hinged knee brace; N/R, not reported; NWB, no weightbearing; PE, pulmonary embolism; postop, postoperative; PWB, partial weightbearing; TF, tibiofemoral angle; TKR, total knee replacement.

durability of the DFO would be important to prevent progression to TKA for as long as possible. Healy et al[11] reported poor outcomes in patients with rheumatoid arthritis. In their series of 23 distal femoral varus osteotomies, 3 knees that had poorer outcomes were in patients with rheumatoid arthritis. These patients had persistent pain after osteotomy, and TKA was later recommended.

While level 4 studies in both the opening- and closing-wedge groups reported improvements in validated patient-reported outcomes, direct comparisons are difficult as most of the studies utilized different scores to report their results or did not report patient-reported outcomes.[14] In those with reported outcomes, a universal measurement was not utilized, and no clear indications, inclusion criteria, or patient selection for the use of DFO were reported. All studies that had patient-reported outcomes reported improvement after surgery compared with the preoperative baseline.

Evaluation of type of graft (ie, autograft vs allograft) among the opening-wedge studies was limited due to the heterogeneity of graft choice. Each of the 5 opening-wedge studies that met inclusion criteria utilized a different graft in their study. Graft choices included allograft,[4] calcium phosphate cement,[5] cortical iliac crest autograft,[12] tricortical iliac crest allograft,[22] and the use of no additional graft.[25] Given the wide variability, no conclusions can be drawn on the optimal graft choice for opening-wedge osteotomies.

Another aim of this study was to determine and compare the complication profile of DFO in both the closing- and

TABLE 4
Patient-Reported Outcomes[a]

Study	HSS Preop/ Postop	IKS Preop/ Postop	Oxford Preop/ Postop	Functional KSS Preop/ Postop	Objective KSS Preop/ Postop	Tegner Preop/ Postop	Lysholm Preop/ Postop	KOOS Preop/ Postop	McDermott Score Preop/ Postop	K-L Grade	Satisfaction Index Score
Closing-wedge DFO											
Backstein et al[2]				54 / 85.6	18 / 87.2						
Finkelstein et al[6]											
Sternheim et al[21]					36.1 / 60.5				36.1 / 60.5		
Kosashvili et al[13]					36.8 / 60.2						
Forkel et al[7]						3.5 / 4.2		Sympt: 55/88.8			
Wang and Hsu[23]	46 (20-63) / 88 (65-99)										
McDermott et al[15]									Improved 28 points		
Healy et al[11]	65 (42-100) / 86 (36-100)										
Learmonth et al[14]											
Opening-wedge DFO											
Das et al[4]	58 / 72						64 / 77				
Dewilde et al[5]				43/ 78						Unchanged	
Jacobi et al[12]	—							31 ± 17 / 69 ± 22			73%
Thein et al[22]	—		13.1 / 26								
Zarrouk et al[25]	—	49.28 (14-70) / 74.23 (41-92)		50.68 (30-80) / 72.85 (40-90)							

[a]DFO, distal femoral osteotomy; HSS, Hospital for Special Surgery; IKS, International Knee Society scoring system; KL, Kellgren-Lawrence score; KOOS, Knee Injury and Osteoarthritis Outcome Score; KSS, Knee Society Score; OA, osteoarthritis; Postop, postoperative; Preop, preoperative; Sympt, symptomatic.

opening-wedge groups. The profile was similar between the 2 groups, with 3 major complications (fracture,[11] n = 1; pulmonary embolus,[15] n = 1) in the closing-wedge group and 2 major complications (fracture,[5] n = 1; postoperative hematoma requiring evacuation,[25] n = 1) in the opening-wedge group. Only 2 studies reported complications for the closing-wedge group.[7,23] Minor complications such as stiffness and postoperative pain appeared in both groups, and the most common complication throughout was plate prominence, discomfort, or irritation over the plate. While rates of required hardware removal secondary to these complications were as high as 72% in 1 group,[7] all remaining articles reported lower rates of hardware removal. Although similar in both groups, the considerable heterogeneity between series precluded statistical analysis. Furthermore, potentially relevant parameters such as obesity, smoking, and compliance with rehabilitation were not reported and could clearly lead to variety in outcomes.

Alignment in both the opening- and closing-wedge groups improved from preoperative baseline and was found to be within the physiologic range in all studies that reported postoperative measurements. However, these measurements should be viewed with caution because only 8 of the included studies reported postoperative measurements as an endpoint, and some studies did not provide preoperative measurements.[12] The reporting of these measurements was also highly variable, with correction presented both as a percentage and in degrees. This limitation in reporting makes comparison and interpretation between the groups difficult, as outcomes and postoperative complications or conversion to total knee arthroplasty could be affected by final alignment. Additionally, the majority of studies did not provide time to bony union after surgery or adequate description of the health of the other compartments of the knee. Failure to report preoperative alignment measurements, the cutoff value to proceed with correction, time to bony healing, or the status of the other compartments of the knee also increases the uncertainty of appropriate patient selection.

Limitations exist within this review as the quality and heterogeneity of the included studies prevented both statistical analysis and direct comparison of the groups. In addition to this, there is a concern for selection bias because none of the articles defined a population from which patients had been drawn, and there are limited data available regarding the process by which patients are selected to undergo this procedure. In addition, absence in preoperative valgus measurements and discrepancies as to whether patients with medial and/or patellofemoral degeneration (in addition to the lateral compartment overload) are candidates for the procedure diminishes utility for the reader. This ambiguity is compounded by the lack of standardization for patient selection as it relates to age, weight, or activity level.

While the available literature does provide some insight as to patient selection and indications for DFO, the choice for opening- or closing-wedge osteotomy is largely physician dependent. Based on the results evaluated in this review, it is not possible to argue for a change in this paradigm.

CONCLUSION

Reasonable survival rates have been reported for DFOs for up to 10 years follow-up with a low complication profile, making this procedure a good option to consider for correction of

nonphysiologic valgus at the knee. However, given the paucity of available data, it is recommended that higher level studies with validated patient-reported outcomes data be pursued in the future in an attempt to better qualify factors for appropriate patient selection, degree of correction required, and postoperative rehabilitation.

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