Received: 13 December 2023 | Accepted: 4 February 2024
DOI: 10.1002/ksa.12097

OSTEOTOMY

Knee Surgery, Sports Traumatology, Arthroscopy WILEY

Derotational distal femoral osteotomy corrects excessive femoral anteversion in patients with patellofemoral instability: A systematic review

Ricardo Ribeiro[1] | **Eluana Gomes**[2] | **Bárbara Ferreira**[1] | **Inês Figueiredo**[1] | **Cristina Valente**[2,3] | **Diego Delgado**[4] | **Mikel Sánchez**[4,5] | **Renato Andrade**[2,3,6] | **João Espregueira-Mendes**[1,2,3,7,8]

[1]School of Medicine, Minho University, Braga, Portugal

[2]Clínica Espregueira-FIFA Medical Centre of Excellence, Porto, Portugal

[3]Dom Henrique Research Centre, Porto, Portugal

[4]Advanced Biological Therapy Unit, Hospital Vithas Vitoria, Vitoria-Gasteiz, Spain

[5]Arthroscopic Surgery Unit, Hospital Vithas Vitoria, Vitoria-Gasteiz, Spain

[6]Porto Biomechanics Laboratory (LABIOMEP), Faculty of Sports, University of Porto, Porto, Portugal

[7]ICVS/3B's–PT Government Associate Laboratory, Braga/Guimarães, Portugal

[8]3B's Research Group-Biomaterials, Biodegradables and Biomimetics, Headquarters of the European Institute of Excellence on Tissue Engineering and Regenerative Medicine, University of Minho, Braga, Portugal

Correspondence
João Espregueira-Mendes, Clínica Espregueira-Dragão-Entrada Nascente, piso-3, 4350-415, Porto, Portugal.
Email: espregueira@dhresearchcentre.com

Abstract

Purpose: Patellofemoral instability (PFI) is a common condition that can be caused from multiple factors, including lower limb rotational malalignments. Determining precise criteria for performing corrective torsional osteotomy can be a daunting task due to the lack of consensus on normal and excessive values and the limited evidence-based data in the postoperative results. The purpose was to assess the clinical, functional and imaging outcomes following derotational distal femoral osteotomy (DDFO) in patients with PFI and/or anterior knee pain (AKP) associated with lower limb rotational malalignments.

Methods: Searches were conducted on PubMed, EMBASE and Web of Science databases up to October 2023. Studies reporting outcomes after DDFO in patients with PFI and/or AKP were eligible for the systematic review. The primary outcome was imaging metrics, especially femoral anteversion. Secondary outcomes included the patient-reported outcome measures (PROMs) (clinical and functional). Quantitative synthesis involved the use of weighted averages to calculate pre- to postoperative mean differences (MD) and compare them against the minimal clinically important difference (MCID).

Results: Ten studies (309 knees) were included with a mean follow-up of 36.1 ± 11.7 months. Imaging outcomes consistently indicated the correction of femoral anteversion (MD = −19.4 degrees, 95% confidence interval: −20.1 to −18.7) following DDFO. PROMs showed significant improvements in most studies, exceeding the MCID. Patient satisfaction with the DDFO was high (93.3%).

Abbreviations: AKP, anterior knee pain; BMI, body mass index; BPII, Banff Patella Instability Instrument; CI, confidence intervals; DDFO, derotational distal femoral osteotomy; IKDC, International Knee Documentation Committee; MCID, minimal clinically important difference; MD, mean differences; MPFL, medial patellofemoral ligament; PFI, patellofemoral instability; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PROMs, patient-reported outcome measures; RoBANS, Risk of Bias Assessment tool for Non-randomized Studies; SD, standard deviation; TTT, tibial tubercle transfer; TT-TG, tibial tuberosity to trochlear groove; VAS, visual analogue scale.

Clinical Trial Registration: PROSPERO registry for systematic reviews (CRD42023401304).

Conclusions: The DDFO was an effective treatment option for correcting excessive femoral anteversion in patients with PFI associated with clinically relevant functional and clinical improvement and a high satisfaction rate.

Level of Evidence: Level IV, systematic review of level II–IV studies

KEYWORDS
anterior knee pain, derotational, distal femoral, osteotomy, patellofemoral instability

INTRODUCTION

Patellofemoral instability (PFI) is a multifactorial condition, often resulting from an interplay of different risks factors, such as patella alta, patellar tilt, trochlear dysplasia, medial soft tissue laxity and lower limb malalignment [5, 18, 23, 27, 29, 30, 32]. Lower limb rotational malalignment, caused by femoral anteversion, may be an important contributing factor in the development of PFI [5]. Femoral anteversion is increased amongst individuals with PFI (measuring 15.6°) compared with individuals without PFI (measuring 10.8°) [5]. Excessive femoral anteversion may result in increased tension on the medial patellofemooral ligament (MPFL) [5, 27] and stress on the lateral patellar facet [19, 22]. This pattern leads to patellar maltracking and increased load at the patellofemoral joint, which can result in a higher risk of lateral patellar dislocation [27]. Excessive femoral anteversion has also been associated with suboptimal clinical outcomes in the treatment of PFI when the abnormal torsion is left untreated [7, 34].

When there is persistent symptomatic excessive femoral anteversion, unresolved after appropriate physiotherapy and medical treatment, femoral derotational osteotomy (either proximal or distal) may become necessary. Derotational distal femoral osteotomy (DDFO) involves cutting and rotating the distal femur, effectively mitigating the lateral force vector induced by excessive femoral anteversion and thereby potentially reducing PFI [14]. However, establishing specific indications for corrective torsional osteotomy can become a complex challenge given the divergence of opinions surrounding measurement techniques, the definition of normative values and the limited evidence-based data.

Despite several studies [9, 31, 33, 37] reporting favourable clinical outcomes, improved patellar tracking and enhanced patellofemoral congruence following DDFO, there is still a need for a comprehensive quantitative assessment of DDFO's impact on patients with PFI associated with lower limb rotational malalignments. The purpose of this systematic review was to measure the correction of femoral anteversion after DFFO in patients with PFI and/or anterior knee pain (AKP) associated to lower limb rotational malalignments. The secondary purpose was to evaluate the improvement in the clinical and functional patient-reported outcome measures (PROMs) in the same sample of patients. It was hypothesized that the DFFO is able to correct excessive femoral anteversion, and that this correction can result in improved PROMs.

METHODS

The systematic review was designed and conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [21] and following the PRISMA–PERSiST consensus recommendations [1]. The protocol for this systematic review was a priori registered in PROSPERO under the number CRD42023401304.

Eligibility criteria

The eligibility criteria are organized following the PICOS framework: Participants, intervention, comparator, outcomes and study design. No restrictions based on the dates of publication were considered for eligibility criteria.

Participants

Studies comprising individuals of both sexes with PFI and/or AKP associated with idiopathic or anatomical causes (such as patellar dislocation or rupture of the MPFL) were included. Participants with PFI and/or AKP associated with fractures, congenital causes (e.g., cerebral palsy), associated hip pathology or history of ipsilateral knee replacement were excluded.

Intervention

Studies that implemented DDFO in patients with PFI and/or AKP were included. All included participants must have undergone at least one DDFO with the goal of correcting lower limb rotational malalignments that were causing PFI or AKP. Due to the multifactorial nature of PFI and AKP, studies that incorporated other complementary surgical procedures, such as MPFL reconstruction, tibial tubercle transfer (TTT) or trochleoplasty, were also considered. Studies that included previous or concomitant knee or patellofemoral arthroplasty or involved other osteotomy procedure than distal femoral osteotomies (e.g., double-level osteotomy or high tibial osteotomy) were excluded. Femoral rotation may also be corrected with diaphyseal femur derotational osteotomies [26] or proximally at the hip with subtrochanteric derotational osteotomies [15]; however, these types of osteotomies are outside the scope of this systematic review and were thus not considered.

Comparator

No head-to-head comparators were required for the study to be included. However, when available, DDFO was compared to other interventions to correct lower limb rotational malalignments (e.g., DDFO with and without MPFL reconstruction).

Outcomes

The outcome metrics eligible for inclusion comprised the two main groups of outcomes: (i) correction of lower limb rotational malalignments (femoral anteversion) evaluated using pre- and postoperative imaging measurements and (ii) measurement of PROMs. Studies needed to include at least one of these two groups of outcomes to be included in the systematic review. No minimum follow-up time was defined as inclusion criteria.

Study design

Any clinical trials (from randomized controlled trials to case series) were considered. A minimum of five patients were required for a case series design to be eligible. All other study designs (letters, editorials, meeting abstracts, cadaveric studies, animal studies, case studies, commentaries, reviews) were excluded. Owing to constraints related to the availability of translation resources, solely studies conducted in the English language were considered.

Search strategy

Searches were conducted up to 27 March 2023, and then updated on 11 October 2023, by searching three databases (PubMed, EMBASE and Web of Science). The full search strategy is detailed in S1. The reference list of pertinent existing reviews related to DDFO, as well as the studies included into this systematic review, were manually screened to ensure the inclusion of all relevant research and uncover any potentially eligible studies that might have been missed during the initial database search.

Study selection

All studies yielded from the database search were exported to 'Mendeley Desktop', where automated deduplication procedures were executed, followed by manual validation for confirmation. Two authors (R. R. and R. A.) conducted an independent review of all titles and abstracts retrieved to identify studies with potential relevance for inclusion. Following this preliminary screening, the full-text of the selected studies was examined to assess whether it met the eligibility criteria. Disagreements were resolved by consensus and, if needed, a third author (C. V.) was involved for arbitrage.

Data collection, extraction and management

Two authors (R. R. and R. A.) were responsible for the extraction and collection of all data acquired from the studies included in the review. Disagreements were resolved by consensus or involving a third author (C. V.) for arbitrage. All data were organized and categorized into distinct subsections: study and population characteristics [first author, year, region, number of patients and knees, age, sex, body mass index (BMI), knee laterality and condition/diagnosis]; surgical procedure characteristics (type of procedure, previous surgeries and follow-up time); and outcomes (preoperative angles, postoperative follow-up angles, preoperative scores, postoperative follow-up scores, satisfaction and complications).

Data were collected as mean and standard deviation (SD) for continuous outcomes, while frequency and percentage (%) were used for categorical data. In instances where mean and SD were not provided, it was sought to calculate these (when feasible) using the methods recommended by the Cochrane Handbook [4]; otherwise, alternative metrics of central tendency and dispersion, such as median, interquartile range, 95% confidence intervals (CI), amongst others, were considered. For small samples ($n \leq 25$), when data were present as median (range), the mean and SD were estimated according to Hozo et al. [11]. For larger samples ($n > 25$) data were presented as median (range or other metric of dispersion). When data were presented in figures or graphs, the WebPlotDigitizer online tool was employed to extract the relevant outcome data.

Risk of bias

The risk of bias of each study was judged according to Risk of Bias Assessment tool for Non-randomized Studies (RoBANS) [16]. This is a validated tool to appraise the risk of bias of nonrandomized studies, comprising six bias domains: (i) selection of participants, (ii) confounding variables, (iii) measurement of exposure, (iv) blinding of outcome assessment, (v) incomplete outcome data and (vi) selective outcome reporting (S2). For the 'measurement of exposure' and 'blinding of outcome assessment' domains, the risk of bias was judged at outcome-level (i.e., subgrouped by imaging and PROMs/clinical outcomes). Each domain was judged as low risk of bias, high risk of bias or unclear. Two authors (R. R. and R. A.) judged the risk of bias of all studies and disagreements were discussed until consensus.

Data management and quantitative synthesis

All summary measures were computed as weighted to the sample size. In cases where only the median was provided, the median values were used (instead of the mean) to compute the weighted averages. When eligible studies had overlapping samples [34–36], it was retained in the study with highest sample size.

All outcomes were reported at both the baseline and follow-up stages. In cases where there was more than one follow-up endpoint, the data at the last follow-up were used. For each outcome at each study that provided data at both baseline and follow-up, the within-group mean difference (MD) was computed (along with its SD and 95% CI) using a correlation coefficient of 0.5. When the study provided data for each participant, then the MD, SD and 95% CI were manually calculated without using the correlation value. The p value for within-group statistical differences (baseline to follow-up) was presented as reported in the original studies. However, if the study did not report the p value but the baseline and follow-up data were available to calculate the MD, then the statistical significance was interpreted as if the 95% CI did not include the value zero.

For the summary of outcome results, a pre-to-post meta-analysis was performed to better display the pooled outcomes in a forest plot. It was used a fixed-effects model to calculate the unstandardized MD. Although the heterogeneity (I^2) was expected to be high, it was decided to perform the fixed-effects model to only display the results showing the MD unstandardized and to thus allow an easier clinical interpretation (which would not be possible by using the effect size or standardized MD under the random-effects model). The forest plot of pre-to-post meta-analysis was only conducted for the main imaging outcome (femoral anteversion angle) and for PROMs that were reported in at least three studies. Subgroup analysis was conducted to compare the results of femoral anteversion angle between based on the indication (femoral anteversion angle) for DDFO. Meta-analysis procedures were made using the 29.0 version of the Statistical Package for the Social Sciences (SPSS; IBM).

To determine the clinical significance of improvement in PROMs, the within-group MD was compared to the minimal clinically important difference (MCID) reported in the scientific literature, specifically for the International Knee Documentation Committee (IKDC) score (change of 9.9 points) [24], Lysholm score (change of 11.1 points) [24], Kujala score (change of 9.1 points) [24], Tegner score (change of 0.9 points) [24] and visual analogue scale (VAS) for pain intensity (change of −2.46 points) [25]. The pooled MCID was calculated by contrasting the pooled MD (meta-analysis) with the MCID cut-off for each PROM. The MCID for the Banff Patella Instability Instrument and activity rating scale has not been determined so far.

RESULTS

Search results

The initial database and hand searches generated a total of 5260 records, of which 50 full texts were screened to assess their eligibility. Amongst these, a total of 10 studies [2, 3, 6, 10, 17, 20, 28, 31, 36, 37] met the eligibility criteria and were included in this systematic review (Figure 1).

Risk of bias

All studies had four or more domains judged as high risk (Figure 2). The 'selection of participants' domain was judged as high risk of selection bias in all studies, mostly due to inclusion of different age groups in the same sample individuals. All studies exhibited high risk of selection bias in the 'confounding variables' domain, due to heterogeneity in age, sex, previous and concomitant surgeries. Three studies [3, 6, 37] demonstrated a low risk of performance bias regarding imaging outcomes, while six studies [2, 10, 20, 28, 31, 36] exhibited a high risk, predominantly attributed to unreported pre- and post-operative values. The remaining study [17] was judged as unclear since it did not report the follow-up time. All studies showed high risk of performance bias regarding PROMs mainly due to a follow-up time less than 24 months or their retrospective design. Additionally, all studies showed high risk of detection bias for all outcomes except one study [9] that reported blinding of imaging outcomes assessors. All

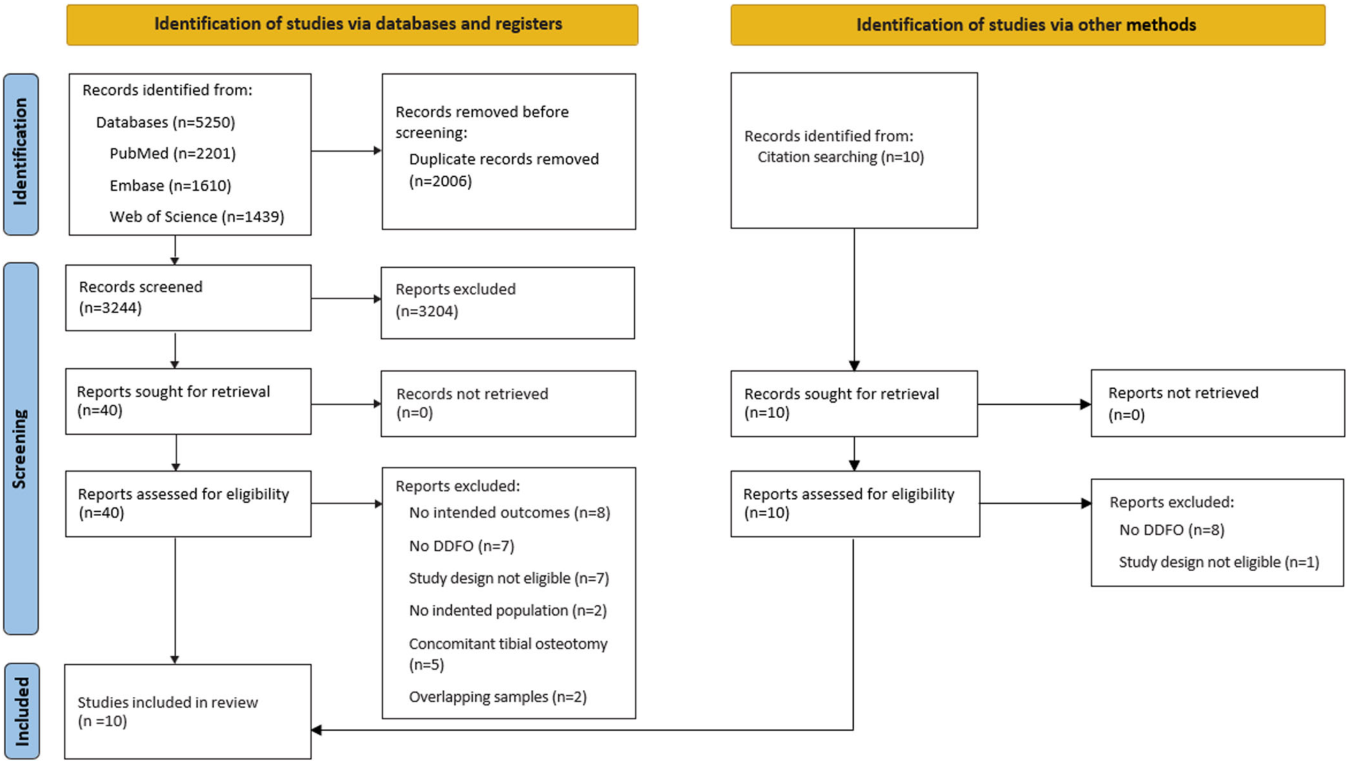

FIGURE 1 PRISMA 2020 flow diagram. DDFO, derotational distal femoral osteotomy; PRISMA, preferred reporting items for systematic reviews and meta-analyses.

studies were judged as having low attrition bias since none of them had missing data in >5% of outcome variables. High risk of reporting bias was detected in only one study [37] due to inconsistencies in reporting results compared to the described methods.

Study and population characteristics

Most studies were conducted in China ($n = 7$), with only three studies coming from European countries, including Germany ($n = 2$) and Switzerland ($n = 1$). All studies were published within the last 8 years. All studies, except one [17], documented the mean follow-up duration, resulting in a weighted average of 36.1 ± 11.7 months.

A total of 309 knees from 295 individuals (84% women) with a weighted mean age of 22.3 ± 3.3 years were included for analysis. Seven studies ($n = 250$) [3, 6, 10, 28, 31, 36, 37] reported the average BMI, resulting in a weighted mean of 22.6 ± 1.9 kg/m^2. Six studies ($n = 241$ knees) [3, 6, 10, 28, 36, 37] provided information regarding knee laterality, which was well-distributed: 51% ($n = 122$) underwent DDFO on the left side, while 49% ($n = 119$) did so on the right side. All included patients had PFI with increased femoral anteversion and 257 patients had, at least, one documented patellofemoral dislocation [2, 3, 6, 10, 28, 31, 36, 37]. No study focused on patients with AKP without PFI. Amongst the studies analysed in this systematic review, six defined excessive femoral anteversion with a threshold of 25° [6, 10, 20, 28, 31, 37], while three used 30° [3, 17, 36] (S3).

Concomitant and previous surgical procedures

A total of 253 knees (81.8%) underwent combined MPFL reconstruction [3, 6, 10, 20, 28, 36, 37] and 26 knees (8.4%) were submitted to simultaneous TTT (medialization or distalization) [36]. Other less common concomitant procedures include deepening trochleoplasty ($n = 9$, 2.1%) [2], medial retinaculum plasty ($n = 20$, 4.7%) [31] or reefing ($n = 5$, 1.2%) [28]. Only Konrads et al. [17] did not perform any concomitant procedure to the DDFO (S4).

A total of four studies [2, 3, 20, 36] documented cases of previous knee surgical procedures, specifically: MPFL reconstruction ($n = 24$), medial retinaculum reefing ($n = 8$), TTT medialization ($n = 1$) and elevation of the lateral condyle ($n = 1$). Four studies [6, 10, 28, 37] did not report any case of previous surgery, and the remaining two studies [17, 31] did not report whether their patients had any previous knee surgery.

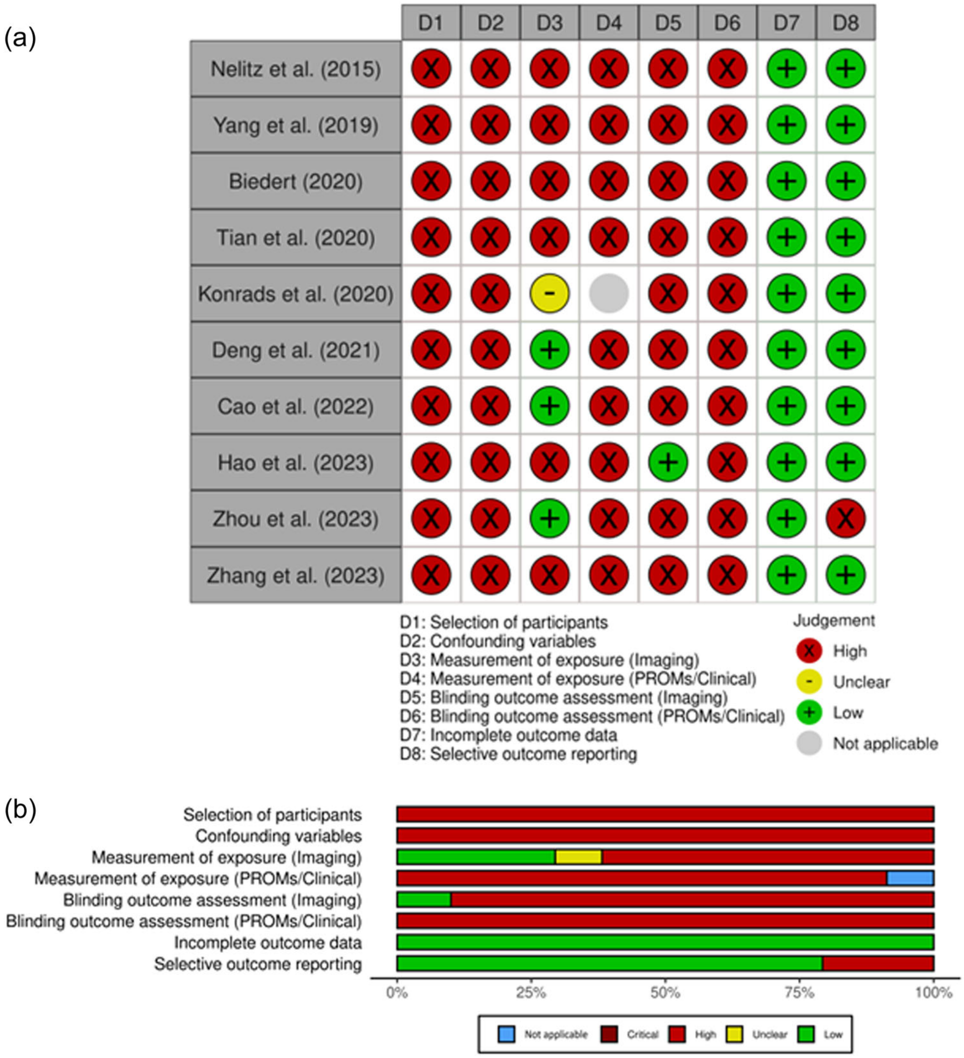

FIGURE 2 Risk of bias judgement: (a) for each individual study; (b) overall summary of all included studies. PROM, patient-reported outcome measures.

Imaging outcomes

Lower limb rotational alignment was assessed using computed tomography femoral anteversion angle [eight studies (3, 6, 10, 17, 28, 31, 36, 37)] and tibiofemoral rotation angle [one study (36)]. Both measures showed a statistically significant improvement in all studies (S5). More specifically, the femoral anteversion angle showed a pooled MD of −19.4 (95% CI: −20.1 to −18.7; $I^2 = 91\%$; Figure 3). When compared the correction of femoral anteversion angle according to the surgical indication, those patients with an indication of ≥30° of femoral anteversion angle for the DDFO showed a significantly superior amount correction of the femoral anteversion angle than those with an indication of ≥25° of femoral anteversion angle (S6).

Lower limb mechanical and anatomical axes were reported using an array of different metrics: mechanical axis angle, mechanical medial proximal tibial angle, mechanical lateral proximal and distal femoral angles, anatomic mechanical angle of the femur and anatomical femorotibial angle (S5). Although with opposing angulation at baseline, the mechanical axis angle was significantly corrected towards zero in both Konrads et al. [17] and Deng et al. [6] studies. The mechanical medial proximal tibial angle, mechanical lateral proximal femoral angle and anatomic mechanical angle of the femur did not reveal any significant improvement [17]. In contrast, the anatomical femorotibial angle showed a statistically significant change at follow-up [6]. Lastly, the mechanical lateral distal femoral angle showed conflicting results, with Konrads et al. [17] reporting a significant decreased (−2.3 ± 2.0°), whereas Deng et al. [6] showing a significant increase (5.9 ± 2.9°).

The PFI-specific imaging metrics included patellar tilt angle [six studies (3, 10, 28, 31, 36, 37)] and patellar

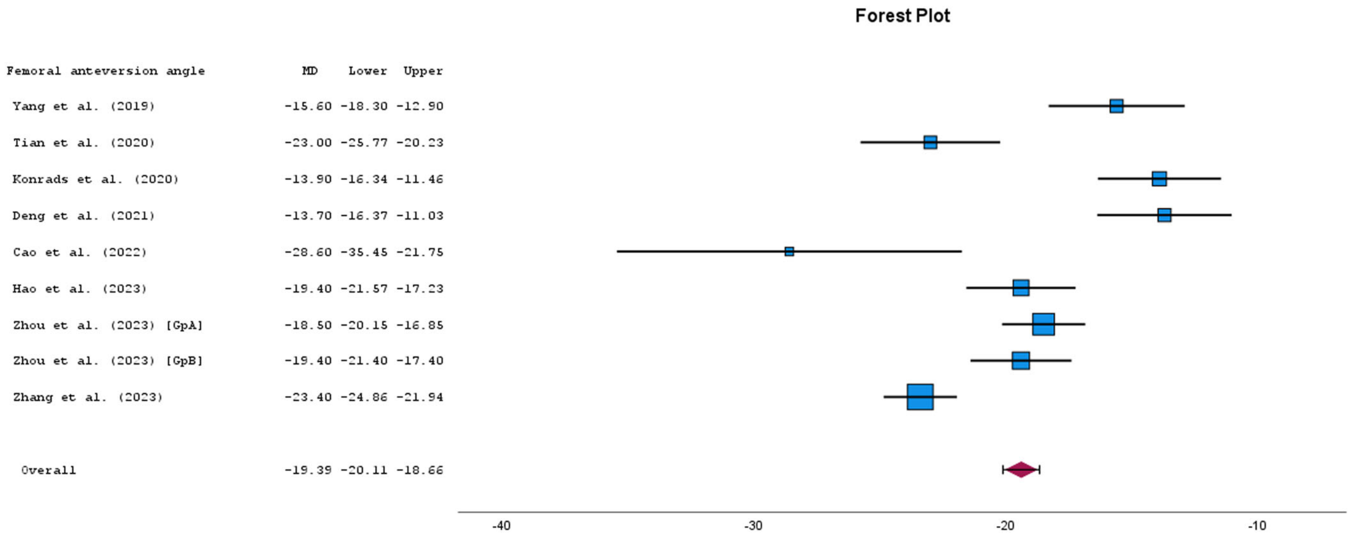

FIGURE 3 Forest plot for femoral anteversion angle (°). G1, grade 1 J-sign group; G2, grade 2 J-sign group; G3, grade 3 J-sign group; GpA, Dejour type A trochlear dysplasia group; GpB, Dejour type B, C, D trochlear dysplasia group; MD, mean difference.

congruence angle [two studies (10, 31)] for patellar angulation; tibial tuberosity-trochlear groove distance [TT-TG; seven studies (3, 6, 10, 28, 31, 36, 37)], patella-trochlear groove distance [one study (10)] and patellar laxity index [one study (3)] for patellar medio-lateral position; and Caton–Deschamps index [three studies (3, 6, 37)] for patellar height (S5). The metrics for patellar angulation and position showed a statistically significant improvement in all studies, except Cao et al. [3], who did not show a statistically significant change in TT-TG. For patellar height, Zhou et al. [37] documented a statistically significant improvement, while Deng et al. [6] and Cao et al. [3] did not.

PROMs and satisfaction

All functional PROMs showed statistically significant improvement from baseline to follow-up (Figure 4): Kujala score (MD = 26.9, 95% CI: 24.7−27.5; I^2 = 76%); IKDC score (MD = 25.6, 95% CI: 24.1−27.2; I^2 = 82%); Lysholm score (MD = 24.4, 95% CI: 22.9−25.8; I^2 = 81%). Furthermore, they had a mean improvement greater than the established MCID: Kujala with 295.6% (173.6%−460.4%); IKDC with 258.6% (204.0%−342.4%); Lysholm with 219.8% (176.6%−272.1%). The VAS score showed statistically significant improvement from baseline to follow-up in all studies that reported it (S7) with a statistically significant pooled improvement of −3.0 (95% CI: −3.2 to −2.9; I^2 = 16%) and a pooled MCID of 122.0%; however, when analysing for each individual study, the improvement did not always surpass the MCID value (93.5%−142.3%). The Tegner score did not show statistically significant improvement in two studies [20, 31] and did not surpass the MCID value in those specific cases (33.3% and 55.6%); however, it showed a significant pooled MD of 1.6 (95% CI: 1.4−1.7; I^2 = 82%) and a pooled MCID of 177.8% (33.3%−355.6%).

Satisfaction was collected using non-validated and heterogeneous methods across studies. It was documented in five studies [2, 10, 20, 28, 31] with an overall satisfaction rate of 93.3% (82.4%−100%).

Complications

Nine studies reported on DDFO-related postoperative complications [17]. There were 33 postoperative complications, with the most common being knee pain (n = 9) and knee stiffness (n = 8). No study reported any patient with residual instability or any episodes of redislocation. There were no intraoperative complications reported (S8).

DISCUSSION

The main finding of the present study is that DDFO is effective in the treatment of patients with PFI by correcting the femoral torsional malalignment (femoral anteversion angle). The femoral torsional correction was also associated with significant and clinically relevant improvements of knee function and pain intensity, resulting in high patient satisfaction. However, these results should be read with caution as there was high risk of bias in most studies (selection, confounding variables, performance and detection bias) which may have influenced the results and highlighted by the high heterogeneity. Moreover, while the DDFO was mostly responsible for correction of excessive femoral

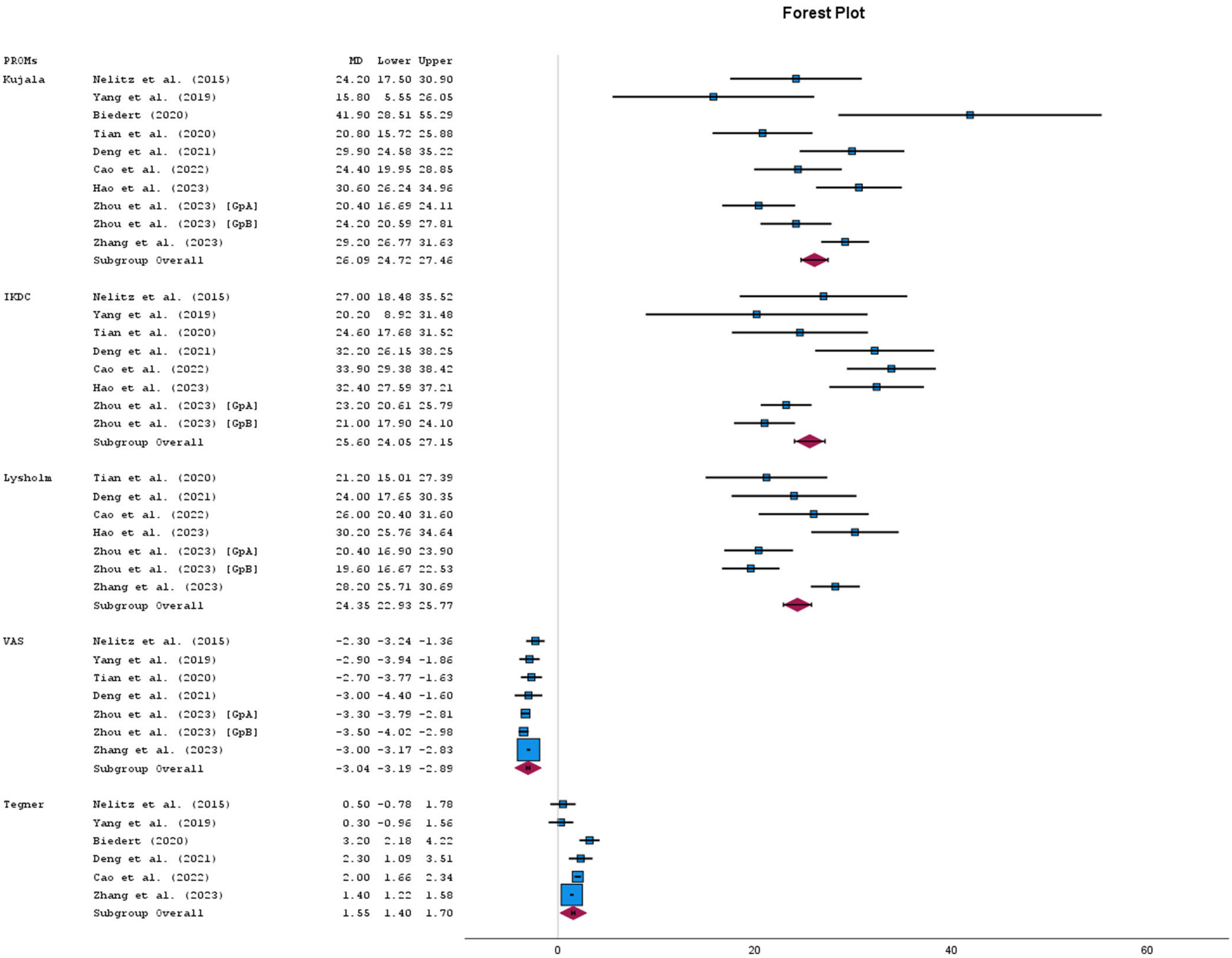

FIGURE 4 Forest plot for PROMs, subgrouped by type of score. G1, grade 1 J-sign group; G2, grade 2 J-sign group; G3, grade 3 J-sign group; GpA, Dejour type A trochlear dysplasia group; GpB, Dejour type B, C, D trochlear dysplasia group; IKDC, international knee documentation committee score; MD, mean difference; PROMs, patient-reported outcome measures; VAS, visual analogue scale.

anteversion, the clinical and functional improvements might also have been associated to the concomitant procedures made at the patellofemoral joint. As the nature of PFI is multifactorial, many risk factors often need to be corrected concomitantly, and it is expected that their resolution have also contributed to the improvements in metrics of patellofemoral joint alignment and those seen in PROMs.

Comparing to similar existing systematic reviews conducted by Zhang et al. [33] and Hao et al. [9], the present systematic review encompasses a broader spectrum of evidence, incorporating a total of 10 pertinent research studies. The present systematic review excludes studies that analysed patients undergoing concomitant knee and patellofemoral arthroplasty alongside DDFO, which was not the case of the other available systematic reviews [9, 33] that included the Imhoff et al. [12] study that had patients with concomitant patellofemoral asthroplasty. The Frings et al. [8] study was also included in the previous reviews [9, 33], but excluded in the present systematic review because they included a patient undergoing double osteotomy. The inclusion of these two studies creates a high risk of selection bias due to confounding. By implementing these strict inclusion criteria, the present systematic review provides a more precise and accurate assessment of DDFO's direct impact on the target population. Moreover, the present systematic review includes a more extensive selection of relevant studies (four new studies) which provides an enhanced and comprehensive overview of the available evidence, with a more precise and accurate assessment of DDFO's direct impact in correcting lower limb rotational malalignments (femoral anteversion) in patients experiencing PFI.

Postoperative outcomes

Excessive femoral anteversion angle emerged as a unanimous inclusion criterion to perform the DDFO. The cut‐off values for excessive femoral anteversion varied between 25° and 30°, which reflects the ongoing debate within the orthopaedic community regarding the optimal cut‐off value that justifies indication for surgical intervention and which may be attributed to differences in the measurement methods. Nevertheless, it is clear that when excessive, the femoral anteversion angle needs surgical correction.

The DDFO showed an overall pooled significant reduction of femoral anteversion angle, which was noted in all eight studies that reported both baseline and follow‐up values [3, 6, 10, 17, 28, 31, 36, 37]. This correction plays an essential role in enhancing patellar stability by decreasing lateral displacement force on the patella and alleviating stress on the MPFL [5, 27, 34]. Patients with an indication of ≥30° (vs. ≥25°) of femoral anteversion angle for the DDFO showed a significantly superior amount correction of the femoral anteversion angle; however, it must be considered that the final corrected femoral anteversion angle of both groups was similar (12.7° vs. 13.1°) regardless of the initial indication, indicating that in both subgroups the DDFO is effective in reducing the femoral anteversion angle to normal values.

The unanimous and significant improvement of all functional score (Kujala, IKDC and Lysholm) and the decrease in pain intensity levels (VAS) demonstrate the ability of DDFO (with or without concomitant surgeries) to improve function and relieve clinical symptoms of patients with PFI. Moreover, the pain intensity [except in Nelitz et al. (20)] and all functional scores exceeded the respective MCID in more than 100%, indicating that the improvements were not just statistically significant but also substantial enough to be considered meaningful from a patient's perspective. Ultimately, the improvement in PROMs reflected in an overall satisfaction rate of 93.3% corroborating the beneficial and positive effect of DDFO in patients with PFI.

Clinical relevance

This systematic review provides strong evidence to support the use of DDFO in correcting an excessive femoral anteversion angle in individuals with PFI. The correction of femoral anteversion angle is associated with a positive and clinically relevant impact on patellar stability, pain relief, functional outcomes and overall patient satisfaction.

Some surgical adjustments may be needed when performing a DDFO. Considering the impact of DDFO on TT‐TG distance, if a surgeon intends to simultaneously perform TTT medialization during DDFO, the cut‐off of TT‐TG should be higher than the traditional value of >20 mm because DDFO itself reduces the TT‐TG distance. To prevent knee valgization, rotational correction proximal to the femoral antecurvature level and perpendicular to the mechanical axis should be considered when necessary. In cases where patients have preoperative genu valgum deformity, biplanar DDFO should be rather considered [6]. However, biplanar DDFO is a meticulous and complex surgery that may be replaced or aided by customized osteotomy guides and plates [13] and/or done with a navigation‐assisted system.

Literature gaps and future directions

One of the existing literature gaps is the lack of comparative studies evaluating DDFO against alternative treatments to correct lower limb rotational malalignments (e.g., high tibial derotational osteotomies or knee arthroplasty) or conservative management approaches. The absence of head‐to‐head comparisons limits the ability to determine the relative efficacy of DDFO in improving patient outcomes as compared to other interventions. To address this gap, it is suggested to prioritize the design and execution of prospective randomized controlled trials that directly compare DDFO with other surgical and conservative interventions. Furthermore, given the prevalence of relatively short follow‐up periods in existing studies, there is a need for future research to prioritize extended follow‐up durations, enabling a more comprehensive assessment of the long‐term sustainability of DDFO benefits. It is also essential to promote the adoption of standardized outcome measures which will enable a more direct comparison of results across studies.

Limitations

This study has several limitations that are inherent to the characteristics of the included studies. All studies included in this systematic review had a retrospective design, characterized by a lower level of evidence. The absence of control groups, except for Hao et al. [10], hindered direct comparisons between patients who underwent DDFO and those who did not. The relatively small sample size reduced statistical power. Nevertheless, given that DDFO is a relatively new procedure (publications included are all from the last 8 years), these limitations are somewhat inevitable and can be reasonably justified. The short follow‐up period hampers the understanding of long‐term outcomes. The majority of the included studies involved concomitant procedures, making it challenging to precisely ascertain DDFO's contribution to patellar stabilization when combined with other interventions. However, this should be expected as the management of patients with PFI in clinical practice typically involves addressing multiple risk factors and integrating several surgical procedures. This systematic review was designed to investigate the effects of DDFO in patients with PFI and/or AKP, but no study was available that focused on AKP. Therefore, no conclusions or recommendations can be drawn for this specific subset of patients. The MCID of PROMs applied in this systematic review were not always specifically validated for patients with PFI, potentially impacting the precision of the results. Some studies presented the data in median (range) format and needed to be converted into mean and SD for result comparisons. Last, some studies [2, 10, 20, 36] lacked reported data for some outcomes at follow-up, preventing a comparison with baseline values.

CONCLUSION

The DDFO is effective in correcting the excessive femoral anteversion angle in patients with PFI. The torsional correction was associated with significant and clinically relevant improvements of knee function and pain intensity, with high patient satisfaction. However, the improvements in patellofemoral joint alignment and PROMs might also have resulted from the associated concomitant procedures.

AUTHOR CONTRIBUTIONS

All authors were involved both in the idealization of the systematic review and preparation of the manuscript. Ricardo Ribeiro and Renato Andrade were involved in the databases searches and data extraction. Ricardo Ribeiro and Renato Andrade performed the data collection and organization in coordination with Inês Figueiredo and Bárbara Ferreira. Ricardo Ribeiro and Renato Andrade performed all data analysis and interpretation of results in coordination with Eluana Gomes and Cristina Valente. Ricardo Ribeiro and Renato Andrade judged the risk of bias of the studies included in the systematic review. João Espregueira-Mendes, Diego Delgado and Mikel Sánchez guided and provided advice during all steps of the development of the systematic review. All authors contributed to drafting and approving the final manuscript prior to submission to the peer-reviewed journal.

ACKNOWLEDGEMENTS

The authors have no funding to report.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The authors declare that the data supporting the findings of this study are available within the article.

ETHICS STATEMENT

Non-applicable for this type of study.

ORCID

João Espregueira-Mendes http://orcid.org/0000-0001-7429-4900

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Ribeiro R, Gomes E, Ferreira B, Figueiredo I, Valente C, Delgado D, et al. Derotational distal femoral osteotomy corrects excessive femoral anteversion in patients with patellofemoral instability: a systematic review. Knee Surg, Sports Traumatol, Arthrosc. 2024;1–12. https://doi.org/10.1002/ksa.12097