

Outcomes of double level osteotomy for osteoarthritic knees with severe varus deformity. A systematic review

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Abstract – Background: When correcting severe genu varus deformity, knee surgeons must choose between performing a single or double-level osteotomy. This systematic review aims to provide this equipoise with some clarity. *Patients and methods:* We conducted this study following the Preferred Reporting Items for Systematic Reviews and Meta-analyses Statement (PRISMA) and the Cochrane Handbook for systematic reviews and meta-analysis. Studies evaluating the effect of the double level osteotomy (DLO) or those comparing it to high tibial osteotomy (HTO) from all regions and written in any language were included. *Results:* Six studies were included in this systematic review. They were prepared and analysed using Review Manager V5.0 [Computer Program] (RevMan5). Performing DLO resulted in restoring patellar height, joint-line convergence angle (JLCA), and mMPPTA to normal values. DLO was also more successful at avoiding joint line obliquity (JLO) in severe varus deformity when compared to HTO ($P < 0.001$). No significant difference was reported between the two cohorts regarding the mLPTA. DLO resulted in satisfactory short term KOOS and IKDC scores. The complication rate after DLO was 2.28%. *Conclusions:* DLO showed a low complication rate and satisfactory short term KOOS and IKDACS scores. Randomised control trials with long term follow-up comparing the DLO and HTO are recommended.

Key words: Knee, Osteoarthritis, Double level osteotomy, Osteotomy, Varus knee.

Introduction

Corrective osteotomy of genu varus is a valuable treatment option for active young patients with Unicompartmental Osteoarthritis (UCOA) of the knee [1–4]. The High Tibial Osteotomy (HTO) has shown to be effective in treating mild varus deformity with satisfactory midterm outcomes [5, 6]. Despite its efficacy in mild varus deformity, some authors have reported negative outcomes for HTO in severe varus deformity [7–10]. The HTO correction of severe varus deformity involves cutting a large opening wedge. Removal of this large wedge leads to the abnormal inclination of the lateral tibial plateau and subsequently results in the cartilage of the knee joint experiencing a high shear force [6, 8]. Moreover, HTO can result in abnormal femoral subluxation and straining of the joint capsule, making future Total Knee Arthroplasty (TKA) a challenging procedure [11–16]. As a result of these complications, double level osteotomy (DLO) has been advocated for severe genu varus deformity to restore normal joint alignment [17]. Multiple

studies published more than 30 years ago advocated against the DLO, however, these studies often included patients with rheumatoid knees [18–23]. The surgeons of the time also failed to consider restoration of the mechanical axis of the knee and lacked the detailed preoperative planning associated with DLO today. As such, the advantage of the DLO over the HTO was not widely accepted by the orthopaedic surgeons of that era. The DLO technique has evolved over the last twenty years, and its popularity is steadily growing, particularly in countries like Germany and Japan [24, 25]. Severe genu varus can be defined as having a mechanical Medial Proximal Tibial Angle (mMPPTA) of more than 95° [26, 27], or in some studies, of more than 93° [24]. Other authors defined it as a mechanical tibiofemoral varus angle (mFTA) of $\geq 3^\circ$ [28, 29]. Some authors have also measured the mechanical Distal Femorotibial Angle (mDFTA) and considered an angle of more than 90° as another indication for DLO [7, 30–32]. The degree of varus deformity can also be broadly categorised into “mild” (3°–5°), “moderate” (6°–8° varus), or “severe” ($\geq 9^\circ$) [33].

Despite the abundance of literature examining genu varus, there is still a lack of data with regard to the outcomes and

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efficacy of the DLO as a treatment for genu varus. This study aims to systematically review the outcomes and efficacy of DLO compared to HTO when used in treating knee osteoarthritis with genu varus deformity. The radiological outcomes of patellar height, mechanical medial proximal tibial angle (mMPTA), mechanical lateral proximal tibial angle (mLPTA), and joint-line convergence angle (JLCA) will be evaluated side by side with patient-reported outcomes measures (PROM) such as Knee Injury and Osteoarthritis Outcome Score (KOOS), International Knee Documentation Committee (IKDC). Reported complications of the DLO will also be evaluated.

Materials and methods

We performed this study following both the Preferred Reporting Items for Systematic Reviews and Meta-analyses Statement (PRISMA) and the Cochrane Handbook for systematic reviews and meta-analysis [34]. We conducted an initial search using MEDLINE-OVID, Web of Science, PubMed, EMBASE-OVID, Google Scholar, and Cochrane Library. We used the following keywords and their combinations: Double osteotomy, High tibial osteotomy, and Genu varus. Articles published from 2000 to July 2021 were included in our literature search and were limited to studies in human subjects published in any language. We also cross-referenced the citations of recovered articles to ensure that all relevant studies were captured.

Study selection criteria

All forms of comparative studies which involved patients undergoing DLO or HTN for severe genu varus deformity were included (retrospective/prospective cohorts, RCTs). We excluded all studies published before 2000 as all these studies did not exclude the rheumatoid knees. Moreover, the detailed preoperative planning and restoration of the mechanical axis of the knee were not accurately considered in that days [18–23]. We excluded cadaveric studies, conference abstracts, letters to the editor, and reviews.

Data extraction and analysis

Eligible titles and abstracts identified by the initial search were screened independently by four authors to assess their eligibility for inclusion in the systematic review. Each manuscript was then fully screened by the authors, and a final eligibility assessment for all included studies was performed. Data extraction was completed, and any discrepancies found were resolved by discussion between all reviewers. Collected information included the lead author, year published, publishing journal, country of study, level of evidence, study design, number of centres, study length, number of participants, age, gender, and Body Mass Index (BMI).

Outcome measures

The radiological outcomes of interest were patellar height, mMPTA, mLPTA, and JLCA. The clinical PROMs were KOOS, IKDC, and complications of the DLO.

Results

Study characteristics

Our literature review returned 125 articles when excluding duplicates. Screening of the titles and abstracts revealed 46 articles that were eligible for full-text screening. Thirty-seven articles were then removed for not meeting selection criteria, subsequently leaving six articles that were eligible for quantitative review. A flow chart demonstrating the study selection process is provided (Figure 1). A summary of the characteristics of included papers is provided (Table 1).

Patient baseline characteristics

Our review included a total of 175 knees. The average age of the cohort was 55.9 years (± 5.85 years). Sixty-eight patients (38.85%) were female, and 107 were male (61.15%), and the cohort had an average BMI of 28.12 kg/m² (± 2.94). A table summarising the patient demographics is included (Table 2).

Systematic review

Radiological results

Patellar height

Two studies reported on the patellar height. Akaoka et al. [35] did not report any significant difference between the two cohorts with regard to patellofemoral biomechanics. However, Fürmetz et al. [36] reported a significant reduction in the patellar height for the HTO group compared with the DLO cohort.

Mechanical medial proximal tibial angle (mMPTA)

Four studies reported on mMPTA. Feucht et al. [33] analysed radiographs of 303 knees in order to determine the ideal osteotomy level to avoid JLO. About 63% of knees required a DLO to correct mMPTA, while in 12% HTO was appropriate for correction. However, when allowing for 2 degrees of over-correction, the percentage of HTOs significantly increased to 57% of knees while 33% required DLO. Other studies reported DLO showed improved restoration of mMPTA to normal values while avoiding JLO when compared with HTO in severe genu varus deformity ($P < 0.001$) [7, 24, 36].

Mechanical lateral proximal tibial angle (mLPTA)

Three studies compared postoperative mLPTA between the DLO and HTO cohorts. No significant difference was reported between the two cohorts [33, 35, 36]. Other non-comparative studies reported satisfactory postoperative mLPTA alignment after DLO [25, 37–39].

Joint-line convergence angle (JLCA)

Four studies reported on the JLCA. All four found that DLO corrected JLCA more successfully than HTO in severe genu varus deformity ($P < 0.05$) [16, 33, 37, 39].

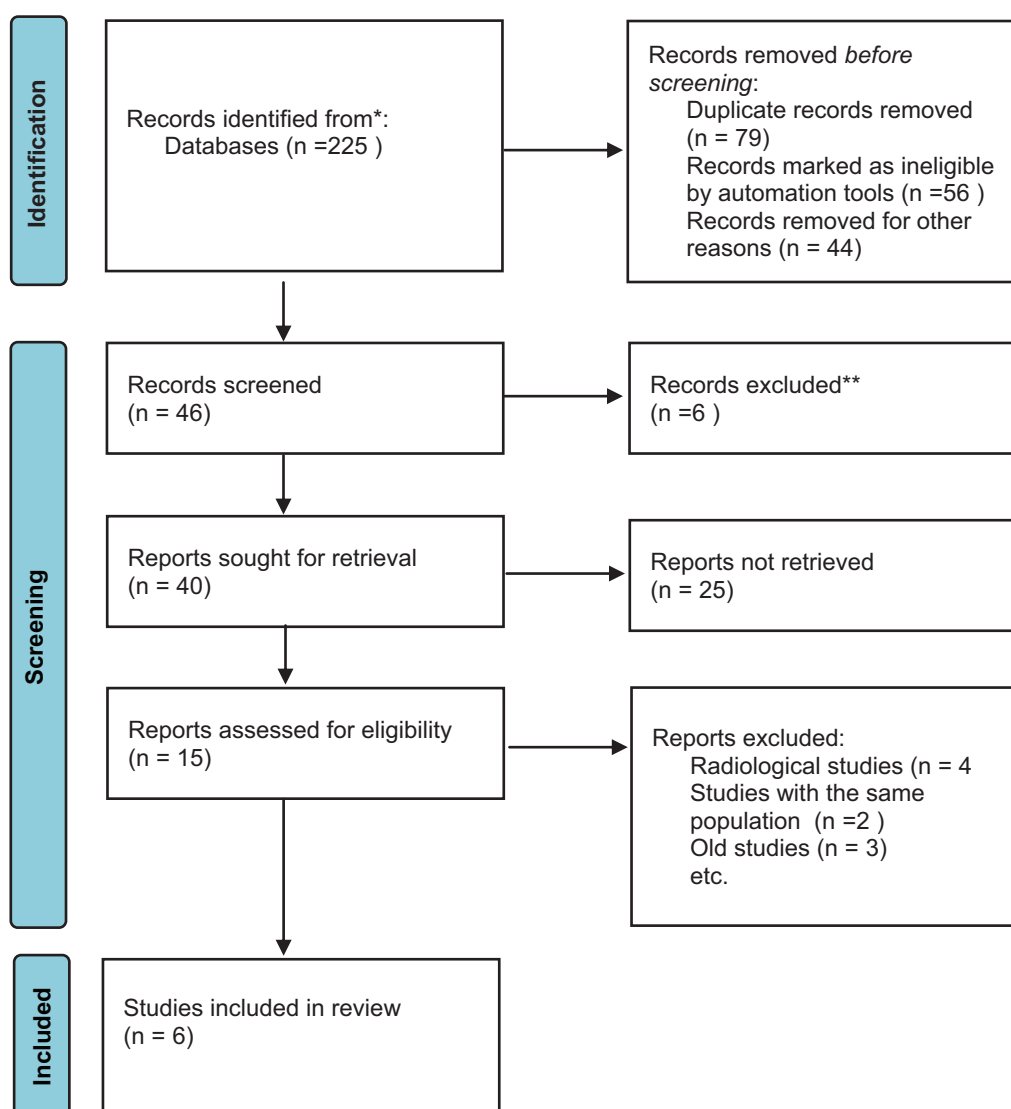


Figure 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow chart.

Table 1. Study's characteristics.

Study	Journal	Type of study	Level of evidence	Numbers of DLO	Numbers of MHTO
Akaoka et al. [35]	ASMARK	RCS (double arm)	II	26	26
Nakayama et al. [16]	Knee Surgery, Sports Traumatology, Arthroscopy	Retrospective case series	IV	20	NA
Babis et al. 2002	JBJS	Prospective case series	NA	24	NA
Hai et al. [37]	Progress in Rehabilitation Medicine journal	Retrospective case series	NA	26	NA
Saragaglia et al. [40]	International Orthopaedics (SICOT)	Retrospective case series	NA	38	NA
Schröter et al. [24]	AOTS	Retrospective case series	IV	33	NA

ASMARK: Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology, AOTS: archives of orthopaedic and trauma surgery, JBJS: The Journal of Bone and Joint Surgery.

Table 2. Patient demographics.

Study	Gender	Age DLO	Age MHTO	PROM	Height	Follow-up months	BMI
Akaoka et al. [35]	3 M, 23 F, (3 M/23 F)	62.3 (6.8)	62.3 (5.6)	HKA angle, mL DFA, mMP TA, Modified Insall-Salvati Index, Modified Caton-Deschamps Index, Modified Blackburne-Peel Index, Lateral patellar tilt, Lateral patellar shift	1.57 (7.6), 1.57 (7.1)	35.5 (8.0), 39.0 (4.9)	24.6 (2.5), 24.5 (2.7)
Nakayama et al. [16]	5m, 15 F, (5 M/15 F)	62.5 (6.8)	NA	mTFA, mL DFA, mMP TA, and JLCA, KOOS and IKDC	NA	20.7 (6.8)	NA
Babis et al. [7]	22 M, 2 F, (22 M/2 F)	50	NA	Mechanical tibiofemoral angle (mTFA), Mechanical deformity, Medial plateau force distribution, Range of joint-line obliquity, Collateral ligament tension	1.74	82.7	30.1
Hai et al. 2020	15 M, 11 F, (15 M/11 F)	60.2 (4.7)	NA	JKOM, JOA, Range of knee extension, Range of knee flexion, Total arc of range of motion of knee, Hip-knee angle, and α angle	159.7 (7.0)	6	26.7 (2.9)
Saraglia et al. [40]	29 M, 9 F, (29 M/9 F)	50.9 (7.1)	NA	Lyshölm-Tegner score, KOOS score, HKA angle, MPTMA, MDFMA.	1.71	46 (27)	29.3 (4.3)
Schröter et al. [24]	23 M, 5 F (23 M/5 F)	50 (9.7)	NA	mTFA, mL DFA, MP TA, and Lequesne-, Lysholm-, Oxford-, and IKDC-score	NA	18	29.9 (5.0)

SD: standard deviation, NA: Not applicable, BMI: Body Mass Index.

Clinical outcome

Knee Injury and Osteoarthritis Outcome Score (KOOS)

Two studies reported on KOOS. They both reported a significant improvement in KOOS at six, twelve, and 46 months after DLO ($P < 0.05$) [16, 40].

International Knee Documentation Committee (IKDC) score

Three studies reported on the IKDC score. DLO resulted in a significant improvement in IKDC at six and twelve months compared to mean preoperative IKDC score ($P < 0.05$) [7, 16, 24].

Complications

Four out of 175 patients (2.28%) suffered complications after DLO. One patient sustained an injury to the popliteal artery during the distal femoral osteotomy [16]. Another patient developed a wound infection three months postoperatively and was successfully treated with oral antibiotics [37]. One patient suffered a fracture of the medial hinge after distal femur osteotomy and subsequently required revision surgery [24]. The fourth patient developed postoperative valgus deformity due to collapse of the supracondylar part of the DLO. This was due to inadequate fixation [7] Table 3.

Discussion

The most important findings in this study are the relatively low complication rate of the DLO and the satisfactory postoperative KOOS and IKAC scores. A 3D finite element analysis study reported high shear stress at the medial tibial plateau

following correction of more than 5° using HTO [16]. Thus, some authors advocated using a DLO to correct any varus deformity with mMP TA more than 95° [16, 41, 42]. Furthermore, Schuster et al. [29] reported unfavourable outcomes at ten years follow-up in 73 patients with mMP TA $> 95^\circ$ who underwent HTO. Overcorrection of varus deformity with HTO failed to change the outcome at two years follow-ups [43]. Of note, an mMP TA of 95° with a JLO of 5° is not an indication for correction as it is compensated by changes in both the ankle and hip joints [44–46]. Some authors advocate against the DLO as it requires delayed weight-bearing after the surgery, however, a recent study proved that the rehabilitation after DLO can start on day 3 post-surgery with the achievement of full weight-bearing after 4 weeks [37]. The favourable outcomes of DLO, when compared to HTO, stem from multiple factors. In advanced genu varus, the lateral compartment of the knee is usually pristine due to the preoperative unloading. Additionally, DLO results in less tension on the knee's ligaments due to equal distribution of loads over the whole knee after deformity correction. Furthermore, the DLO corrects the varus deformity of the knee without residual JLO, subsequently decreasing the shear stress at the lateral femoral condyle and changing the load over the medial compartment by 5% [16, 47]. Of note, the recent less invasive techniques in DLO have reduced morbidities and the theoretical disadvantage of postoperative decrease in the arc of movement [19]. Feucht et al. [33] reported that with overcorrection of the varus deformity, 65% of patients could be corrected with a single osteotomy, either HTO (57%) or DFO (8%). Only 33% of patients with severe varus deformity require DLO.

Babis et al. [7] reported the indication and outcomes of the DLO for advanced varus deformity. They also performed a postoperative computerised assessment using an Osteotomy Analysis and Simulation Software (OASIS). They reported

Table 3. Complications.

Study	Complications	Numbers of DLO	Percentage
Akaoka et al. [35]	None	26	0%
Nakayama et al. [16]	A major intraoperative arterial injury was encountered in a 44-year-old female patient. In this case, the popliteal artery was injured during the distal femoral osteotomy.	20	5%
Babis et al. [7]	In one knee, the supracondylar part of the double osteotomy collapsed into excessive valgus one week postoperatively because of insufficient fixation/ The two undercorrected knees had a 74% and 87% residual medial overload	24	4.17%
Hai et al. [37]	One case of wound infection at the tibial site was diagnosed 3 months postoperatively and was successfully treated with oral antibiotics.	26	3.85%
Saragaglia et al. [40]	No	42	0%
Schröter et al. [24]	One patient had a complication with a fracture of the medial hinge after distal femur osteotomy; this resulted in an overcorrection, and the problem was solved with revision surgery.	37	2.7%
Total	4	175	2.28%

satisfactory survival at 8.33 years follow-up with a failure rate of 5%. A similar technique used preoperative computerised templating and intraoperative navigation system to determine the desired amount of correction and was reported by other surgeons as having an excellent outcome [7, 38]. Thus, the surgical technique is a keystone for satisfactory outcomes. The use of a rigid fixation decreased the recurrence rate and achieved satisfactory outcomes at mid to long term follow-up [16]. Based on the findings of this review, severe varus deformity is successfully and satisfactorily corrected by DLO.

Study limitations

Limitations of this study include the relatively low volume of data collected and the number of studies included.

Conclusion

DLO showed a low complication rate and satisfactory short term KOOS and IKDAC scores. Randomised control trials with long term follow-up comparing the DLO and HTO are recommended to further compare the two options.

Conflict of interest

The authors declare that they have no relevant financial or non-financial interests to report.

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Ethical approval

Ethical approval was not required.

Informed consent

This article does not contain any studies involving human subjects.

Authors' Contributions

All authors had made impactful contributions to the manuscript submitted. The first author was involved in selecting the included studies during the process of screening, study design, statistical analysis and drafting of the review. The second author was involved with data extraction, data analysis and interpretation, the third and the fourth authors played an essential role in this study, providing necessary guidance and mentorship.

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