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EDITORIAL

Knee Surgery, Sports Traumatology, Arthroscopy WILEY

Critical considerations in the selection between knee osteotomy and unicompartmental knee arthroplasty in younger patients with varus alignment and early-stage knee osteoarthritis

INTRODUCTION

Younger patients presenting with varus related painful knee conditions pose a significant challenge in surgical decision-making [14]. The decision between knee osteotomy (KO) and unicompartmental knee arthroplasty (UKA) is influenced by a complex interplay of factors that extend beyond traditional considerations such as patient age, activity level [11, 12], or prevailing surgical philosophies [2–4, 7, 8].

This editorial seeks to elucidate the primary objective and quantifiable factors that guide the decision-making process between KO and unicompartmental arthroplasty [4, 10, 17]. Drawing on insights from the existing literature [9, 20, 25, 35], it aims to present a simplified decision-making framework based on two key equations that assess both the type of deformity (intra-articular vs. extra-articular) and its anatomical location (femur, tibia or both) [28, 36].

It is important to emphasise that this decision-making tool is intended exclusively for native knees with no prior history of fracture or osteotomy, where anatomical landmarks remain intact and reliable. Furthermore, the proposed algorithm does not address cases involving multicompartmental degenerative changes or valgus knee deformities [2].

Two basic case presentation help to introduce the philosophy behind the algorithm described in this editorial:

In the first case (Figure 1), the patient exhibited an isolated intra-articular varus deformity with symptomatic medial compartment osteoarthritis. After thorough evaluation of the deformity's characteristics and screening for contraindications—such as ligament insufficiency or inflammatory arthropathy—a UKA was selected as the optimal intervention.

In the second case (Figure 2), the patient demonstrated a primarily extra-articular varus deformity—predominantly tibia vara—accompanied by medial compartment overload and pain. Following shared decision-making, a high-tibial osteotomy was performed to realign the mechanical axis and offload the medial compartment.

The analysis performed during those to cases follow the Analyzer for Knee Unicompartmental Medial Arthritis (AKUMA®) Principles (Figure 3).

DEFINING DEFORMITY AND ITS ROLE IN LOWER LIMB ALIGNMENT PHENOTYPING

The accurate analysis of lower limb alignment is crucial for selecting the appropriate surgical intervention. Literature has highlighted the importance of global alignment parameters in predicting outcomes following knee surgery [32, 33, 39]. Key parameters include:

- Global deformity (GD):

$$GD = EAD + IAD.$$

- Medial proximal tibial angle (MPTA): Defines tibial deformity (TD)

$$TD = 87 - MPTA \text{ in varus knees.}$$

- Mechanical lateral distal femoral angle (mLDFA): Defines femoral deformity (FD)

$$FD = LDFA - 87 \text{ in varus knees.}$$

- Joint line convergence angle (JLCA): is a powerful Indicator of intra-articular deformity (IAD), which has been shown to influence soft tissue behaviour and surgical planning. The JLCA also reflects the degree of joint wear, as a normal JLCA is unlikely in the presence of osteoarthritis [23].

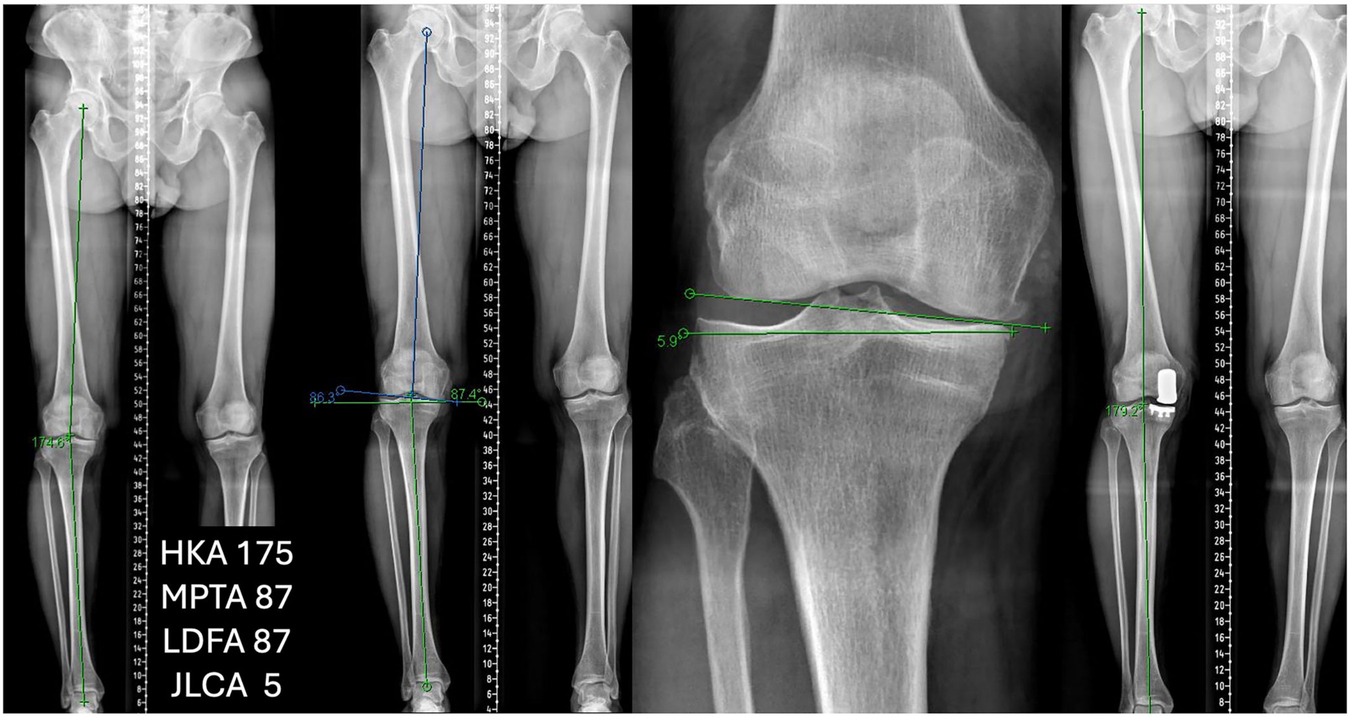

FIGURE 1 (Fifty shade of) varus deformity almost strictly intra-articular? HKA 175/) MPTA 87/LDFA 87/JLCA 5. IAD% = 100%. EAD% = 0%. Patients received a UKA. EAD, extra-articular deformity; HKA, hip-knee-ankle angle; IAD, intra-articular deformity; JLCA, joint line congruency angle; LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle; UKA, unicompartmental knee arthroplasty.

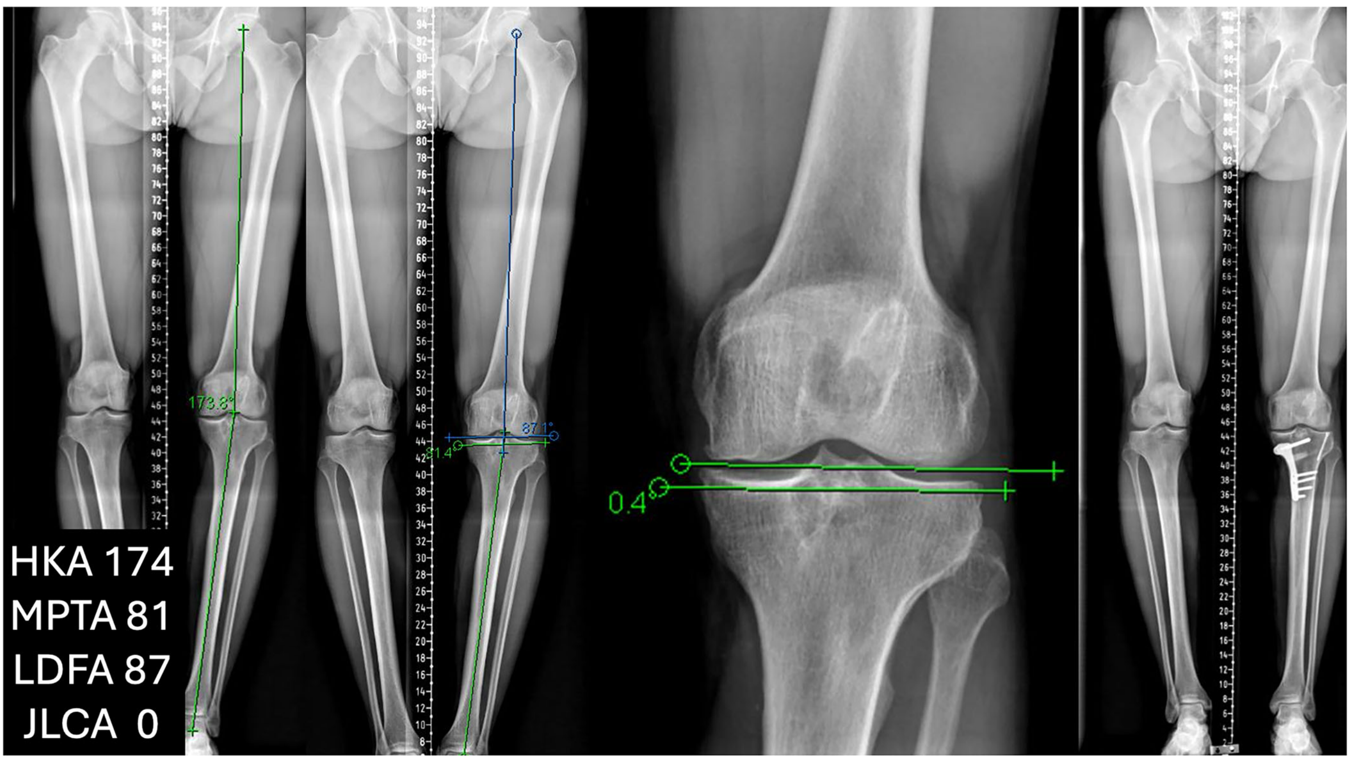

FIGURE 2 (Fifty shade of) varus deformity almost strictly in the tibia. HKA 174/) MPTA 81/LDFA 87/JLCA 0. IAD% = 0%. EAD% = 77%. TD = 100%. FD = 0%. Patients received HTO. EAD, extra-articular deformity; FD, femoral deformity; HKA, hip-knee-ankle angle; IAD, intra-articular deformity; JLCA, joint line congruency angle; LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle; TD, tibial deformity.

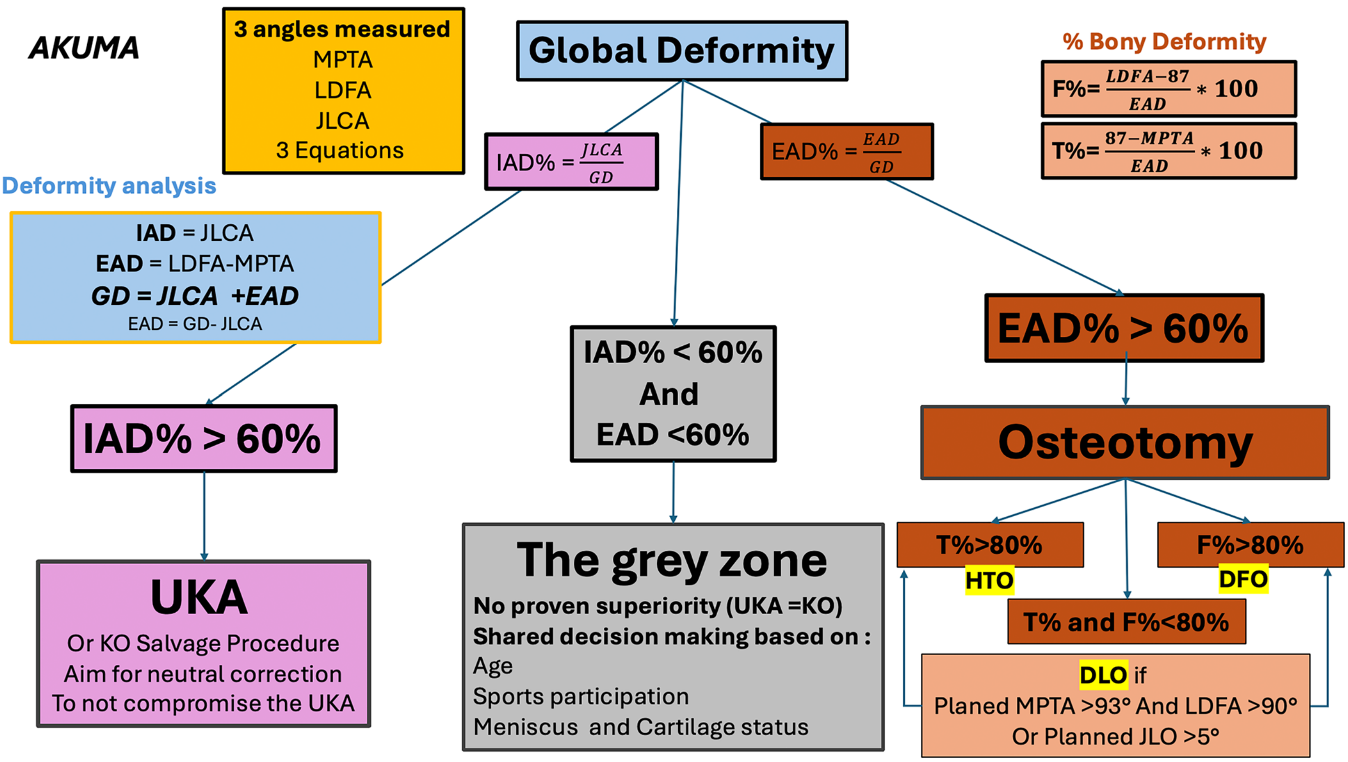

FIGURE 3 Akuma algorithm. DLO, double level osteotomy; EAD, extra-articular deformity; GD, global deformity; IAD, intra-articular deformity; JLCA, joint line congruency angle; KO, knee osteotomy; LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle; UKA, unicompartmental knee arthroplasty.

IAD can be defined as Absolute JLCA value (positive in varus/negative in valgus)

$$\text{IAD} = \text{JLCA}.$$

- In rare instances, an extra-articular deformity may be partially compensated by an opposing intra-articular degenerative process—for example, a valgus-aligned lower limb presenting with medial compartment osteoarthritis. In such cases, the following must be adjusted, as the opposing deformities may counterbalance each other rather than summing linearly.
- Extra-articular deformity (EAD)

$$\text{EAD} = \text{LDFA} - \text{MPTA} \quad \text{in} \quad \text{varus knees}.$$

Finally, the following equation can be used to calculate GD in varus knees:

$$\text{GD} = \text{LDFA} - \text{MPTA} + \text{JLCA}.$$

These parameters offer a systematic framework for characterising lower limb deformities and have been validated as critical elements in guiding patient-specific treatment strategies [3].

A STRUCTURED EQUATION-DRIVEN METHOD FOR SIMPLIFYING TREATMENT DECISIONS

Traditional factors such as age and activity level often bias the decision toward KO for young and active patients, whereas UKA is favoured in older, lower-demand individuals. However, numerous studies [7, 29] suggest that the primary determinant should be the location of deformity:

- IAD: Often necessitates an intra-articular solution such as UKA
- EAD: Advocates for deformity correction using KO

A proposed sequential equation approach can streamline decision-making: the first equation is to determine if it is an intra- or extra-articular deformity. The second equation is to determine the contribution: femur or tibia or both of the EAD.

Again, IAD is determined by the calculation of JLCA which is often positive in the varus deformity.

Once GD, IAD, EAD, TD and FD are known the decision can be based on the following sequence:

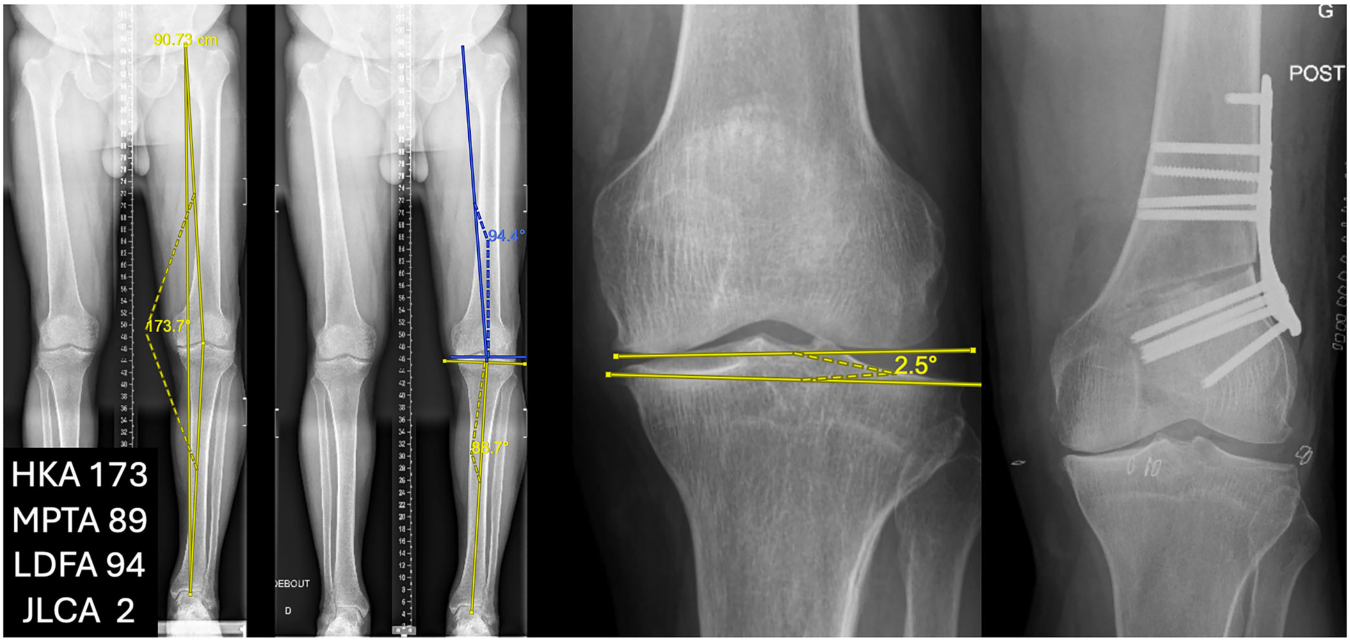

FIGURE 4 (Fifty shade of) varus deformity almost strictly in the femur. HKA 173/) MPTA 89/LDFA 94/JLCA 2. IAD% = 37%. EAD% = 62%. TD = −20% (valgus tibia). FD = 77%. Patients received a DFO. DFO, distal femoral osteotomy; EAD, extra-articular deformity; FD, femoral deformity; HKA, hip-knee-ankle angle; IAD, intra-articular deformity; JLCA, joint line congruency angle; LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle; TD, tibial deformity.

1. Deformity location analysis:

$$IAD\% = \frac{IAD}{GD}$$

$$EAD\% = \frac{EAD}{GD}$$

When the IAD% exceeds 60%, intra-articular interventions—such as partial joint replacement—are generally expected to yield better outcomes than osteotomy. Conversely, when the EAD% is greater than 60%, the deformity is primarily of extra-articular origin, and correction through osteotomy is typically associated with improved knee function and postponement of prosthetic solutions.

In cases where both IAD% and EAD% are below 60%, the patient falls into a clinical 'grey zone' where both treatment options offer comparable potential. In such scenarios, the decision should be made collaboratively, taking into account factors such as patient age, activity level, extent of joint degeneration, ligament integrity, and other variables known to influence early failure rates of either osteotomy or UKA [22, 21].

2. Relative contribution of tibial versus femoral deformities to extra-articular malalignment (EAD):

$$T\% = \frac{TD}{EAD} \times 100$$

$$F\% = \frac{FD}{EAD} \times 100$$

TD/EAD and FD/EAD ratios can guide the choice between high tibial osteotomy (HTO), distal femoral osteotomy (DFO; Figure 4), or double-level osteotomy (DLO; Figure 5):

- The deformity can then be defined using a simple percentage definition (e.g., of 8° varus deformity, EAD > 60% 2 showing a substantial extra-articular deformity which located 75% at the tibia and 15% at the femur) (Figure 1).
- The discussion of DLO can be discussed based on recent ESSKA consensus [5, 31, 6]) when the femoral deformity is >3° (or isolated HTO create a high risk of abnormal postoperative JLO (MPTA > 93) when there is a substantial femoral deformity LDFA > 90°).

SALVAGE CONSIDERATIONS—WHEN KO IS NECESSARY DESPITE HIGH IAD

Certain patients—particularly young, athletic individuals with combined intra- and extra-articular deformities—may still be candidates for osteotomy

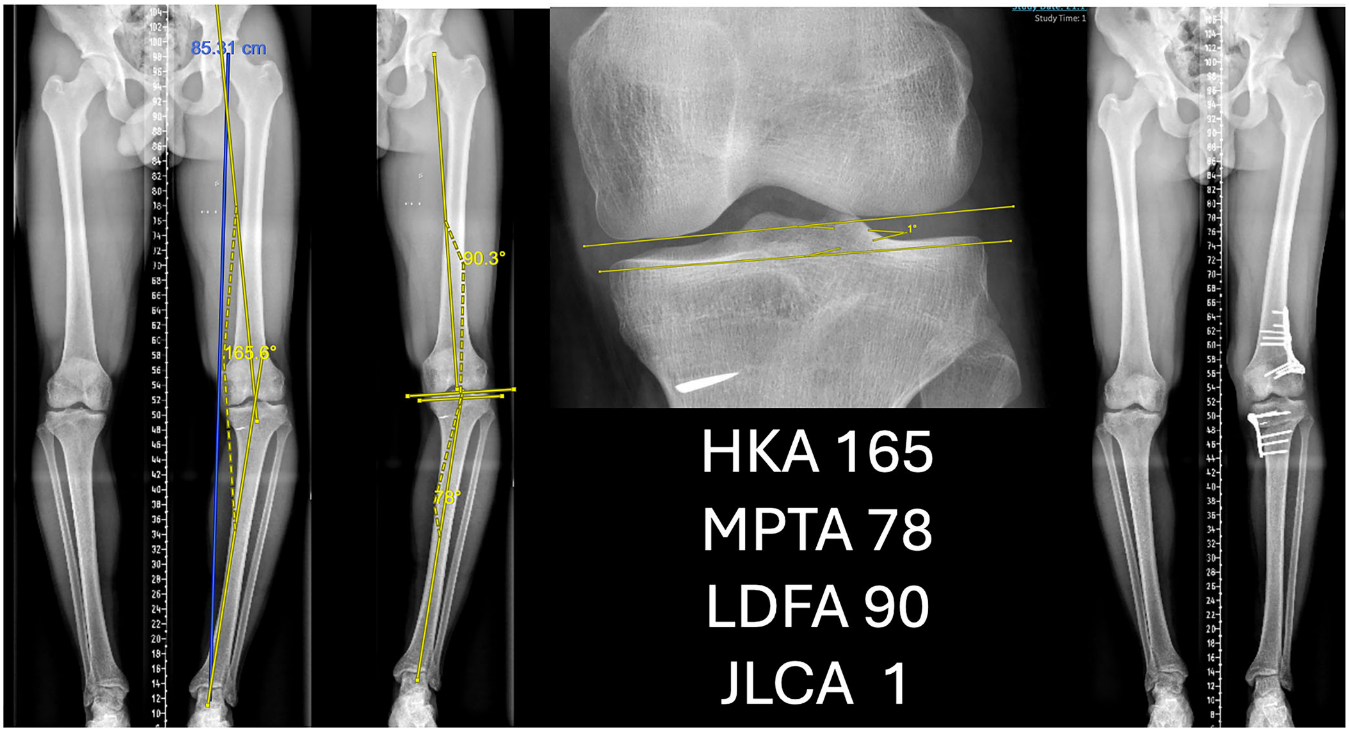

FIGURE 5 (Fifty shade of) varus deformity balance in both femur and tibia. HKA 167/MPTA 78/LDFA 91/JLCA 1. IAD% = 14%. EAD % = 86%. TD = 60%. FD = 40%. GD was 13° and femoral deformity was >3°, the patient received a DLO. DLO, double level osteotomy; EAD, extra-articular deformity; FD, femoral deformity; GD, global deformity; HKA, hip-knee-ankle angle; IAD, intra-articular deformity; JLCA, joint line congruency angle; LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle; TD, tibial deformity.

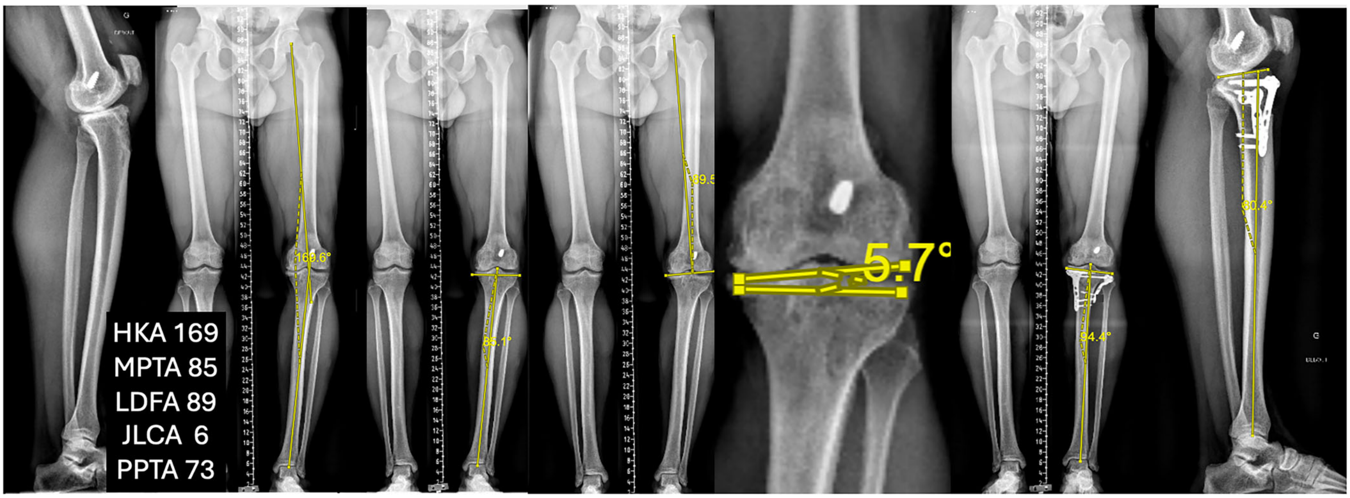

FIGURE 6 (Fifty shade of) varus deformity with both intra- and extra-articular deformity in a young rugby player with knee instability, medial meniscus complete meniscectomy and recurrent instability). This case highlights the 'grey zone' in our treatment algorithm, where choosing between unicompartmental knee arthroplasty (UKA) and high-tibial osteotomy (HTO) requires a shared, informed decision-making process. We thoroughly reviewed the risks and benefits of both procedures with the patient. Given that instability was the primary concern for this active rugby player—and noting that HTO would additionally reduce the posterior tibial slope—we jointly elected to proceed with a biplanar closing-wedge HTO, fully acknowledging the potential for postoperative joint-line obliquity. HKA 169/MPTA 85/LDFA 89/JLCA 6/posterior proximal tibial angle (PPTA) 73. IAD% = 55%. EAD = 45%. TD = 50%. FD = 50%. Since achieving an HKA of 182° required a 13° correction, the planned postoperative MPTA was expected to exceed 92°. To mitigate the risk of overcorrection, the JLCA-2/2 formula was applied, leading to a reduction of the osteotomy wedge to 10°. EAD, extra-articular deformity; FD, femoral deformity; IAD, intra-articular deformity; JLCA, joint line congruency angle; LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle; TD, tibial deformity.

TABLE 1 Summary of reported evaluation methods for ΔJLCA reported from Micioi et al. [27].

Author	Year	JLCA in supine position (mean ± SD)	JLCA in standing position with weight-bearing conditions (mean ± SD)	JLCA under varus/valgus stress (mean ± SD)	ΔJLCA
Kubota et al. [15]	2020	–	3.4 ± 2.2° (Single leg)	–	–
Kumagai et al. [16]	2020	2.4 ± 1.6°	5.1 ± 2.0°	–	−1.9° ± 1.4° (postop Day 0–Day 2)
					0.2° ± 1.2° (1 month–12 months)
Akasaki et al. [1]	2019	2.1 ± 1.5°	3.8 ± 2.0°	–	1.1° ± 1.0° (pre – postop on supine)
					−0.7° ± 1.0° (pre – postop on standing x-ray)
Goshima et al. [8]	2019	–	3.2 ± 1.7°	–	–
Tsuji et al. [40]	2019	–	4.1 ± 2.3° (single leg)	6.0 ± 2.4°/1.3 ± 2.1°	7.4° ± 2.7° (pre varus–valgus)
Lee et al. [19]	2018	–	3.4 ± 2.2° (double leg)	Latent medial laxity: JLCA in valgus stress – JLCA in weightbearing standing	–
Takagawa et al. [38]	2019	–	4.4 ± 2.3° (single leg)	6.9 ± 2.2°/1.3 ± 2.5°	8.1° ± 2.8° (preop varus–valgus)
So et al. [37]	2019	2.3°	4.2° (double leg)	6.7°/0.6°	1.8° (supine–standing)
Park et al. [34]	2019	–	3.8 ± 1.9°	5.4 ± 2.1°/1.7 ± 1.4°	1.2° ± 1.5° (preop–postop)
Kim et al. [13]	2017	–	3.1 ± 1.8°	–	–
Ogawa et al. [30]	2016	–	4.6 ± 2.2° (double legs)	5.6 ± 2.4°/1.5 ± 1.8°	2.0 ± 1.5° (preop–postop)
Lee et al. [18]	2016	–	3.4 ± 2.3°	–	–

Abbreviations: JLCA, joint line convergence angle; Postop, postoperative; Preop, preoperative; SD, standard deviation.

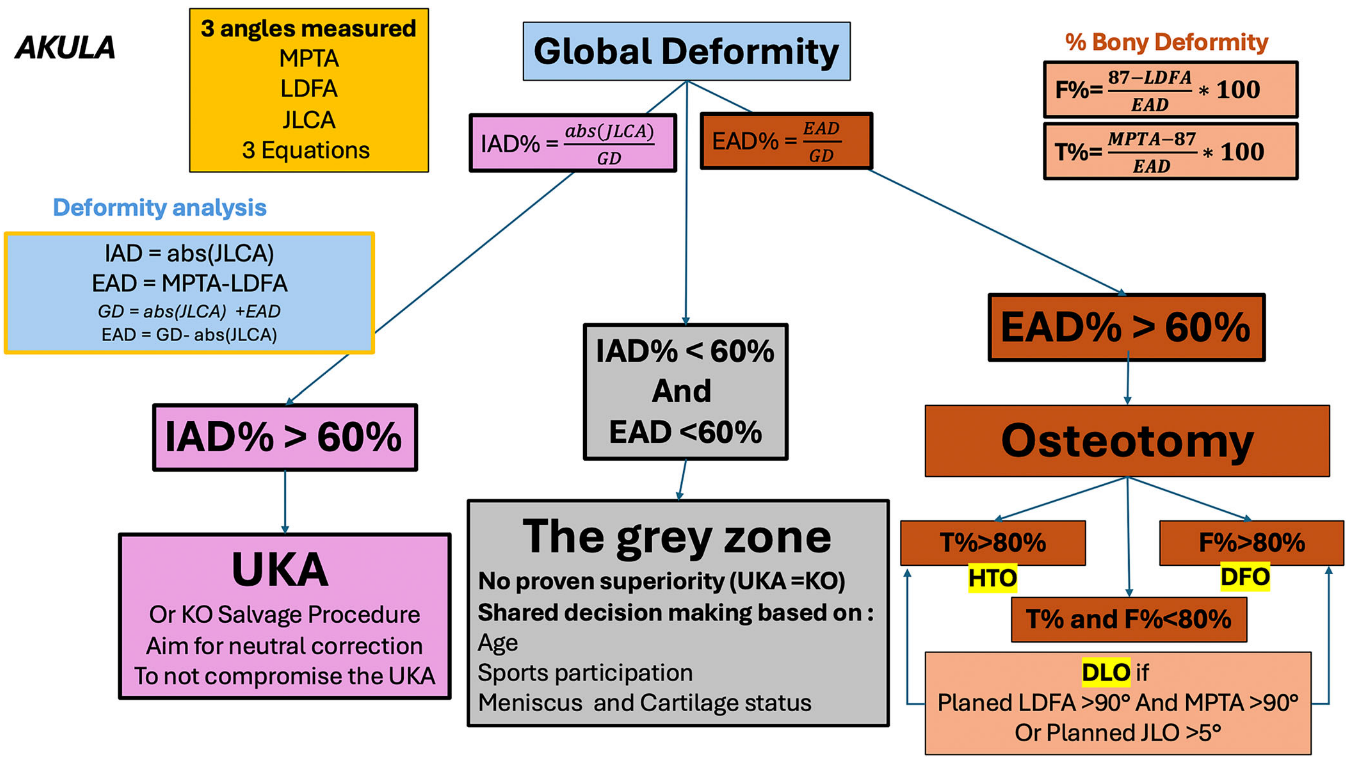

FIGURE 7 Akula algorithm. DLO, double level osteotomy; EAD, extra-articular deformity; GD, global deformity; IAD, intra-articular deformity; JLCA, joint line congruency angle; KO, knee osteotomy; LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle; UKA, unicompartmental knee arthroplasty.

despite a predominance of joint-line malalignment (Figure 6). Anticipating the soft-tissue response is critical: recent studies have shown that ligamentous laxity and periarticular tissue adaptation can alter postoperative alignment if not accounted for [1, 26]. Consequently, when planning osteotomy, one must carefully balance correction of the intra-articular component against the risk of overcorrection, ensuring that residual soft-tissue tension will not inadvertently shift the mechanical axis beyond the intended target.

Various authors proposed ΔJLCA method [1, 8, 13, 15, 16, 18, 19, 30, 34, 37, 38, 40]. which adjusts planning based on soft tissue behaviour, has been validated to significantly reduce planning errors and improve postoperative alignment accuracy.

It is important to note that the JLCA shift (seesaw effect) occurs only when the hypomochlion of the knee joint is reached through osteotomy correction. Mabrouk et al. recently confirmed this and estimated that the seesaw tipping point typically occurs when the MPTA exceeds 92° [24] (Table 1).

While the algorithm described offers a robust framework for varus deformity, valgus knee analysis demands a tailored approach. The distribution of pathological angles differs significantly. Therefore, deformity assessment in valgus knees requires adjusted thresholds and careful interpretation of anatomical landmarks. In particular, the recognition of valgus-specific abnormal values for LDFA, MPTA and JLCA is essential to accurately phenotype the deformity and avoid planning errors. Slight modifications of the standard analysis are thus necessary to reflect the biomechanical reality of valgus malalignment and guide optimal surgical strategy (Figure 7).

CONFLICT OF INTEREST STATEMENT

Matthieu Ollivier, Kristian Kley and Sebastien Parratte are paid consultant and receive royalties from Newclip. Matthieu Ollivier is paid consultant and receive royalties from Stryker. Michael Hirschmann is Editor In chief of KSSTA. Ayoosh Parek has nothing to disclose.

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