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CONSENSUS

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Osteotomy around the painful degenerative varus knee has broader indications than conventionally described but must follow a strict planning process: ESSKA Formal Consensus Part I

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Abstract

Purpose: The European consensus was designed with the objective of combining science and expertise to produce recommendations that would educate and provide guidance in the treatment of the painful degenerative varus knee. Part I focused on indications and planning.

Methods: Ninety-four orthopaedic surgeons from 24 European countries were involved in the consensus, which focused on the most common indications for osteotomy around the knee. The consensus was performed according to an established ESSKA methodology. The questions and recommendations made were initially designed by the consensus steering group. And 'best possible' answers were provided based upon the scientific evidence available and the experience of the experts. The statements produced were further evaluated by ratings and peer review groups before a final consensus was reached.

Results: There is no reliable evidence to exclude patients based on age, gender or body weight. An individualised approach is advised; however, cessation of smoking is recommended. The same applies to lesser degrees of patellofemoral and lateral compartment arthritis, which may be accepted in certain situations. Good-quality limb alignment and knee radiographs are a mandatory requirement for planning of osteotomies, and Paley's angles and normal ranges are recommended when undertaking deformity analysis. Emphasis is placed upon the correct level at which correction of varus malalignment is performed, which may involve double-level osteotomy. This includes recognition of the importance of individual bone morphology and the maintenance of a physiologically appropriate joint line orientation.

For affiliations refer to page 8.

Abbreviations: DLO, double-level osteotomy; HTO, high-tibial osteotomy; KO, knee osteotomy; LCW, lateral closing wedge; MOW, medial opening wedge; OA, osteoarthritis.

Conclusion: The indications of knee osteotomies for painful degenerative varus knees are broad. Part I of the consensus highlights the versatility of the procedure to address multiple scenarios with bespoke planning for each case. Deformity analysis is mandatory for defining the bone morphology, the site of the deformity and planning the correct procedure.

Level of Evidence: Level II, consensus.

KEYWORDS
indications, knee osteotomy, planning, varus knee

INTRODUCTION

Modern knee osteotomy (KO) has evolved dramatically from the dogma of 50 years ago, where a valgising osteotomy for the painful degenerative varus knee conventionally involved a lateral closing wedge high tibial osteotomy (LCW HTO) [2]. In 1974, Jackson and Waugh reviewed a series of HTOs performed with a variety of techniques, with no consensus on the most suitable osteotomy type [14]. Later, further series have demonstrated several disadvantages of the LCW technique [12, 17, 23], which ignited the move towards an opening wedge technique [26, 30]. The current practice is largely dominated by either medial opening wedge high tibial osteotomy (MOWHTO) [19], LCW distal femoral osteotomy [27] or a combination of the two with double-level osteotomy (DLO) [32]. Whilst substantial elements of current osteotomy practice are built on solid foundations with a strong scientific evidence base, the inexperienced surgeon still faces several choices in areas where robust scientific evidence is absent [4]. In general, the coronal alignment was the only aspect taken into account when considering lower limb valgising osteotomy. Currently, more attention is paid to the different long bone morphotypes when considering indications for different osteotomies around the knee. These indications have broadened as experience has been gained. A greater awareness of complications has fine-tuned surgical techniques and modified medical treatments to prevent adverse events [10]. However, recent studies have shown a survival rate after 10 years of up to 90% and 75% in patients after open and closed wedge osteotomy, retrospectively [5]. This consensus scrutinises the scientific evidence base and draws upon the knowledge of experts in the field with in-depth experience of the indications and planning over a period of years in busy osteotomy practices.

This consensus does not attempt to cover the expanding variety and scope of highly specialised periarticular osteotomy techniques or their extended indications. It is a work directed at the surgeon with an 'everyday' osteotomy practice to provide the clearest statements possible to educate, guide and instruct. Part I focuses on the indications and diagnostics of osteotomy in patients with painful varus osteoarthritis (OA).

MATERIALS AND METHODS

The ESSKA European osteotomy consensus process was endorsed by ESSKA and initiated in April 2020. The method was based on the 'Formal Consensus Process' as described by the French National Healthcare Institution (Haute Autorité de Santé HAS; Figure 1), and also specifically published by ESSKA [1].

A total of 94 European surgeons and scientists were involved in the process. All group meetings for the consensus were performed online due to coronavirus disease. The first Steering group meeting/Questions group meeting was on 3 December 2020. The Literature group meeting was 1 week later. This has continued until before the ESSKA Paris 2022.

The steering group consisted of 17 osteotomy experts and included 14 members of the osteotomy committee of ESSKA (Figure 1). The two principal objectives of the Steering Committee were to: (A) devise a framework of questions suitable for consensus and educational purposes and (B) thoroughly evaluate the scientific literature and combine it with expert opinion to produce robust statements.

The steering group was initially subdivided into 'questions' and 'literature' groups. The questions group comprised five experts who formulated a series of enquiries to cover the relevant and important aspects of osteotomy surgery under each of the five headings: indications, planning, surgical strategy, rehabilitation and complications. A total of 39 questions were generated for the consensus.

Parallel to the questions group, a second group was formed with five additional members from the steering group to analyse the relevant literature. A literature search was conducted between June 2000 and December 2020 including PubMed, Google Scholar and EMBASE according to keywords relevant to each specific question. The title and abstract of all references were evaluated, and any relevant article was

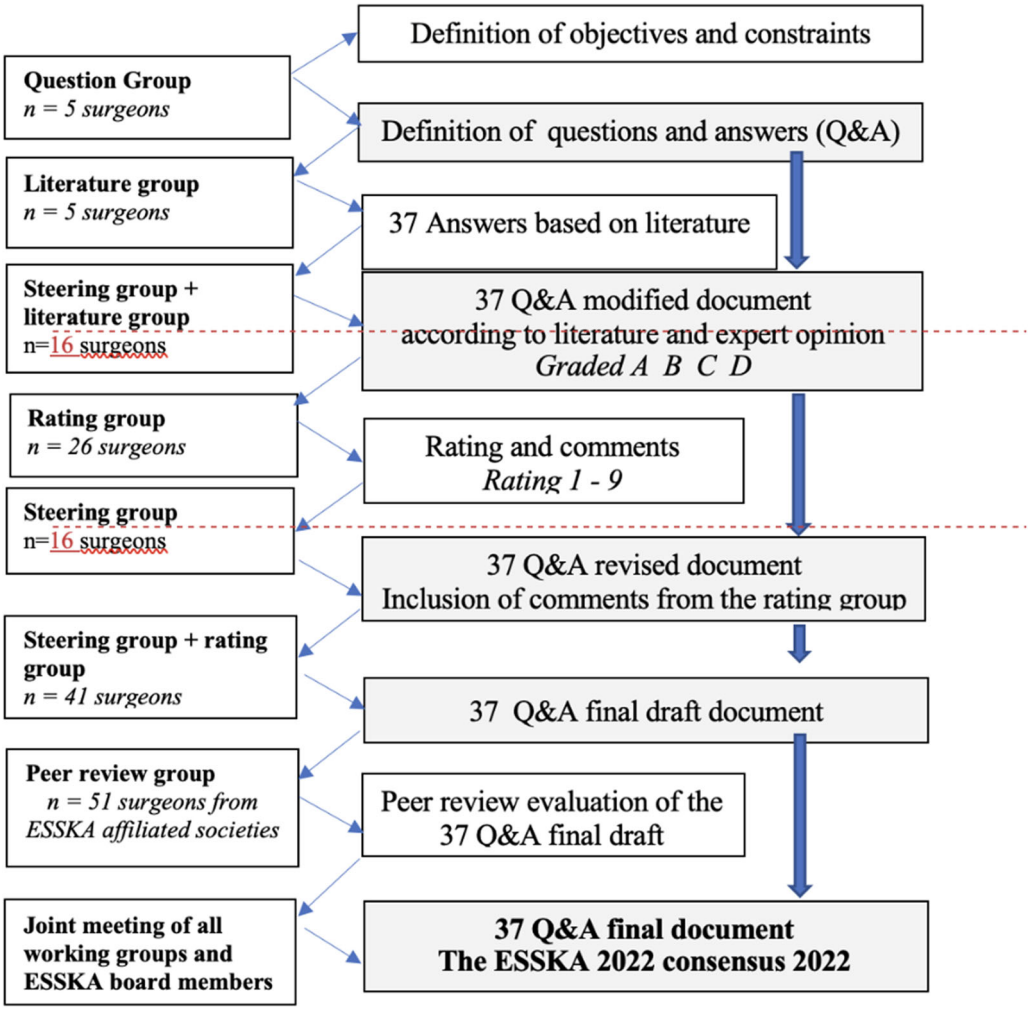

FIGURE 1 Summary of the consensus workflow.

then obtained in full for the steering group to summarise as a brief report. Peer-reviewed clinical studies with levels of evidence ranging from one to five were included in this analysis. Only papers published in English were considered. Historical papers were included when relevant but more attention was paid to papers published in the last two decades. The literature underlined the answers to each question to provide expert statements as evident as possible. The two groups worked independently at the beginning of the project to avoid any bias.

The literature underlined the answers to each question to provide expert statements as evident as possible. Each question–statement pairing was graded based on the scientific level of evidence: A—high scientific level; B—scientific presumption; C—low scientific level and D—expert opinion.

The statements were rated by a group of 26 experienced osteotomy surgeons throughout the European countries. Each expert was asked to evaluate all pairings by using a 1–9-point Likert grading scale. Their recommendation was to be based on their interpretation of the literature and their personal experience. A value of '1' meant that the rater considered the proposal totally inappropriate (for indication or acceptability), whereas a value of '9' indicated that the rater considered the proposal totally appropriate (for indication or acceptability). Values of 2–8 represented possible intermediate situations. A proposal was deemed appropriate when the value of the median was ≥7, and the scores of each rater were ≥5.

The steering committee reviewed the results of the first round of evaluation by the rating group and included modifications where needed before presenting to the rating group for a second round. The proposals on which members of the rating group agreed and on which difference or indecision existed were ratified by means of votes conducted in two rounds and an interim feedback steering group meeting. This evaluation sometimes resulted in a modification of the wording of the question or answer and in two cases with the exclusion of the question-and-answer pairing from the proposed consensus.

The peer group was composed of 51 European surgeons from around Europe who routinely manage patients with varus, painful and degenerative knees and regularly perform osteotomy. They were invited by the executive boards of national subspecialty societies affiliated with ESSKA and were considered a diverse and fair representation of European surgeons managing patients in this field. Their specific role was to review the manuscript draft after the completion of the grading process conducted between the steering and rating groups. They were specifically required to evaluate the recommendations in the document for their relevance to a diverse European readership, together with their geographical adaptability and readability.

The entire project can also be read in more detail on the ESSKA website (http://www.esska.org/page/projects).

RESULTS

Section 1: Indications

(1) Is KO for varus medial OA preferentially indicated for a specific age group or gender?

The general status of the patient is considered more important than age alone. There is no clear cut-off value that preferentially indicates osteotomy at any specific age. Similarly, no outcome data exist to suggest superior or inferior clinical outcomes in younger patients compared with those over 55 years of age. Older patients will enjoy improved outcomes where otherwise appropriate indications are followed (Grade C).

There is no evidence that male or female gender influence KO outcomes (Grade B, Agreement 7.9 ± 2/9).

(2) Do extreme values of body mass index (BMI) contraindicate KO?

BMI influences KO outcomes, with higher complication rates in patients with BMI > 30 or BMI < 21. Whilst no recommendation can be extracted from the literature on a specific 'cut off' value, a case-by-case assessment must be made if the BMI > 35 and patients are counselled regarding the high risks involved (Grade C, Agreement 8.3 ± 1.4/9).

(3) How does the smoking of nicotine products influence the decision to perform osteotomy?

Smoking and nonsmoking patients will all benefit from KO, although smokers must be informed of the increased risks of complications such as infection and delayed union (Grade B).

Smokers should stop nicotine abuse for at least 3 weeks before and 3 weeks after surgery (Grade D, Agreement 8.1 ± 1.4/9).

(4) Is early lateral compartment OA (Kellgren Lawrence grade I or II or Outerbridge grade I or II) a contraindication to KO?

Early signs of OA (diagnosed by radiography, magnetic resonance imaging [MRI] or arthroscopy) do not impair outcomes and are therefore not contraindications to KO surgery, although it is important to recognise the status of the lateral meniscus. KO is a potentially powerful intervention in the younger patient even with early lateral compartment disease. Substantial lateral compartment OA (Kellgren Lawrence grade 3 and 4) is a relative contraindication to KO and may well impact upon final outcome [7]. Positioning of the weight-bearing line (WBL) into the lateral compartment in such a circumstance may accelerate lateral compartment disease. A more neutral positioning of WBL may therefore be a more viable alternative (Grade D, Agreement 7.9 ± 2/9).

(5) Is early lateral patellofemoral OA a contraindication to KO?

Patellofemoral OA (regardless of the diagnostic tool: MRI, radiography or arthroscopy) is not an absolute contraindication to KO. In certain specific cases, adaptations of the conventional technique are recommended to avoid a reduction in patella height (including descending biplanar cut and LCW osteotomy) (Grade B, Agreement 8.4 ± 1.5/9).

(6) Is significant bone loss with intra-articular varus deformity a contraindication to osteotomy?

Intra-articular deformity questions the indication for KO as the usual emphasis is on extra-articular deformity correction (Grade D).

In the case of isolated intra-articular wear, KO outcomes are unpredictable (Grade C).

In case of combined intra- and extra-articular deformity, the amount of 'potential' soft tissue correction should be estimated to avoid massive overcorrection (Grade C, Agreement 8.3 ± 1.1/9).

(7) Is there a risk of metal allergy with materials used in KO?

There is no specific evidence regarding metal allergies in the KO setting. Modern angle stable implants are manufactured from pure titanium and the alloys most commonly associated with a potential for allergy are no longer used. Therefore, in daily practice, it is recommended that the choice of implant is based on conventional principles, even for those patients with 'confirmed' metal allergy (Grade C, Agreement 8.7 ± 0.6/9).

Section 2: Planning

(1) What is the ideal radiographic evaluation to facilitate osteotomy planning?

The gold standard for quantification of coronal alignment is the double leg stance long leg radiograph with the patient appropriately positioned with the limbs correctly rotated so as not to misrepresent coronal alignment (Grade C) (Figure 2).

A standard lateral knee view is a routine requirement. In addition, for sagittal plane deformity analysis and planning, whole-length views of the femur and/or tibia should be performed (Grade D) (Figure 3).

If torsional deformity is suspected clinically, axial plane planning computed tomography (CT) scan slices at predefined heights are preferred (Grade D, Agreement 8.9 ± 0.3/9).

(2) Which measurements should be included in the deformity analysis?

A deformity analysis should precede the planning for correction of a coronal plane deformity and must include measurements of a weight-bearing leg axis, periarticular angles and joint line angles, preferably according to Paley and Pfeil [29] (Grade D).

Sagittal plane (patella height and tibial slope) and axial plane deformity analysis of the femur and tibia can be performed relative to normal values irrespective of the measurement system used for patella height and tibial slope (Grade D, Agreement 8.7 ± 0.4/9).

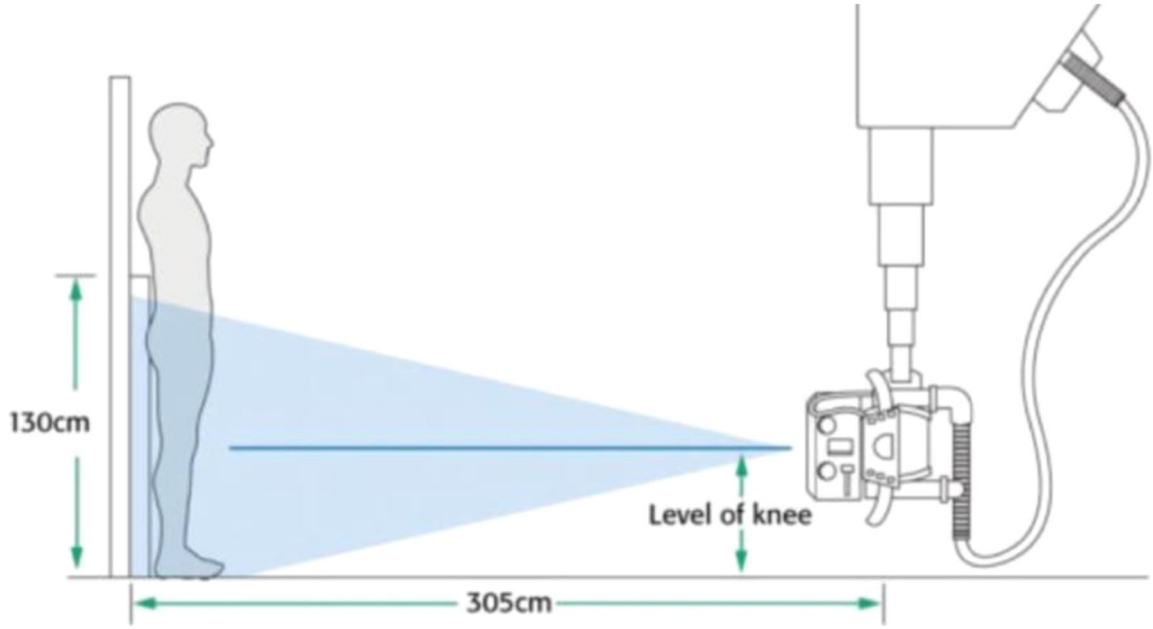

FIGURE 2 Performing long leg alignment radiographs as described by Frank et al. in 1974 [11].

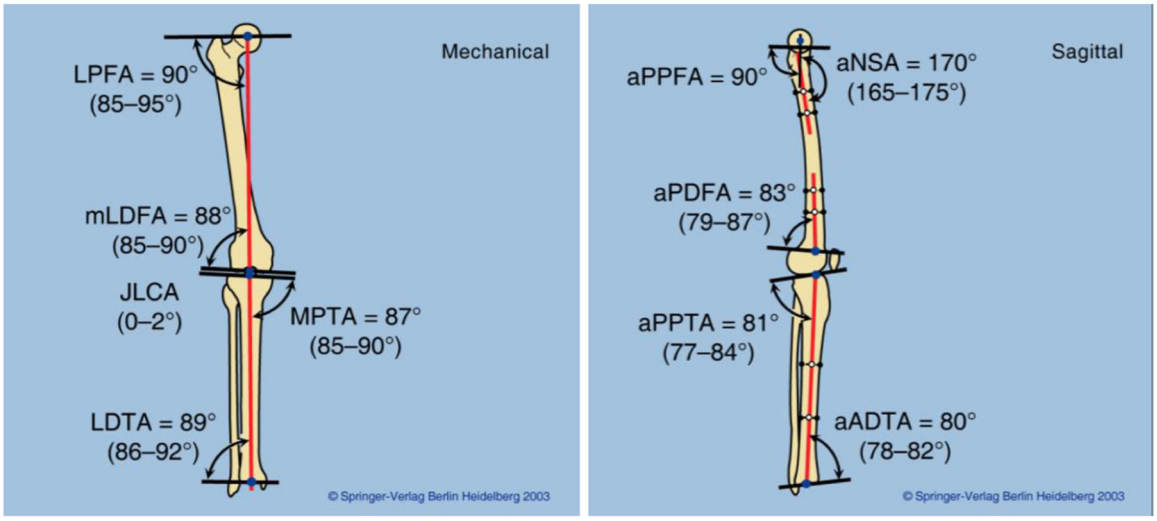

FIGURE 3 Mechanical alignment parameters in the coronal and sagittal planes. Conventionally described by Paley and Pfeil [29]. aADTA, anatomic anterior distal tibial angle; aNSA, anatomic neck shaft angle; aPPFA, anatomic proximal posterior femoral angle; aPPTA, anatomic proximal posterior tibial angle; JCLA, joint line convergence angle; LDTA, lateral distal tibial angle; LPFA, lateral proximal femoral angle; mLDFA, mechanical lateral distal femoral angle.

Digital planning has been demonstrated to have high intra- and interrater reliability when compared to commercially based landmark software [8].

(3) What are the normal values in lower-limb coronal alignment, femoral and tibial morphology? Normal lower limb alignment and standard ranges can be defined according to Paley and Pfeil [29] in the coronal plane. These normal values (Table 1) should be considered in the context of recognised ethnic and gender differences and clinical examination findings (Grade B, Agreement 8.8 ± 0.4/9).

(4) Where does the deformity lie in varus arthritic knees?

A deformity analysis will show in which bone(s) the varus leg alignment is located. If the periarticular bone angles measured do not (fully) account for the leg deformity, then an additional ligament laxity or intra-articular deformity may be contributing to the varus malalignment (Grade B, Agreement 8.9 ± 0.2/9).

(5) Where should the WBL be positioned to treat a knee with medial OA knee in varus malalignment?

An individualised approach is recommended which recognises that each patient has differing characteristics that include degree of deformity, radiographic OA severity and indication for osteotomy surgery. No specific target point can be recommended but based on historic results target ranges of between 50% and 68% have been proposed and may be implemented depending on patient specificity and degree of OA. In light of the more recent evidence relating to joint line obliquity, the consensus group would aim at the lower range of correction (Grade D, Agreement 8.2 ± 1.8/9) (Figures 4, 5 and 6).

(6) Which knee joint line orientation is acceptable after planning an osteotomy?

The knee joint line orientation defined as the position of the knee joint tangent relative to the horizontal is known to be important to reduce shear forces in the knee. Joint line orientation reflects a challenging compromise between mechanical WBL modification and resulting tibial and femoral anatomical morphology. Planning should therefore aim to target a resulting knee joint line orientation below or equal to 5° (MPTA < 95°) (Grade B, Agreement 8.6 ± 0.6/9).

(7) When is a DLO indicated to correct a varus malaligned knee?

A DLO correcting the varus malalignment in both the femur and the tibia should be considered if deformity analysis identifies a significant deformity in both bones. DLO may also be considered when planning a single-level correction, the resultant knee joint line orientation exceeds 5° or MPTA exceeds 94° (Grade C, Agreement 8.7 ± 0.6/9).

(8) How is ankle joint line orientation influenced by osteotomy?

Ankle joint line orientation in the coronal plane is affected by osteotomy around the knee, becoming

TABLE 1 Normal values of lower limb alignment parameters.

Abbreviation	Name	Description	Normal values	References
Mik %	Mikulicz point	Point where the weight-bearing axis (plumb line from hip to ankle) transects a scale from the medial tibial margin (0%) to lateral tibial margin (100%)	35%–55%	[8]
MAD	Mechanical axis deviation	Perpendicular distance from the centre of the knee to the mechanical axis line (femoral centre to ankle centre)	9.7 ± 6.8 mm	[28]
mTFA	Mechanical tibiofemoral angle	Acute angle between the mechanical axes of the femur and tibia	1°–1.3° varus	[28]
HKA	Hip–knee–ankle	Obtuse or reflex angle formed between femoral and tibial mechanical axes	Varus <180° (obtuse) Valgus >180° (reflex)N = 172°	[12] [6]
MPTA	Medial proximal tibial angle	Medial angle between tibial mechanical axis and tibial plateau tangent	87° (85°–90°)	[28]
LDFA	Lateral distal femoral angle	Lateral angle between mechanical femoral axis and femoral condylar tangent	88° (85°–90°)	[28]
TBVA	Tibial bone varus angle	Angle between tibial mechanical axis and the epiphyseal axis of the proximal tibia	2°–5°	[3]
JLCA	Joint line convergence angle	Angle between the femoral condylar tangents and the tibial plateau tangents	0°–2°	[28]

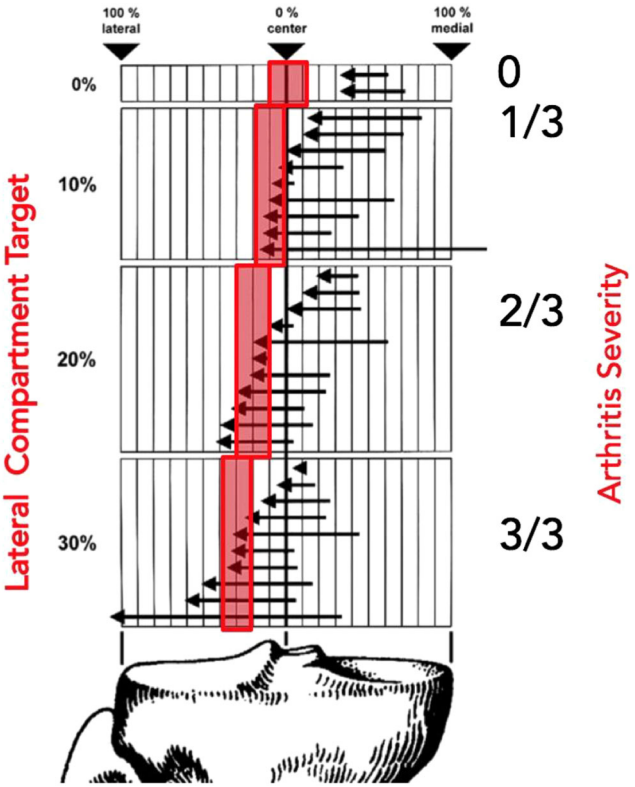

FIGURE 4 Marti et al. [22] proposed that the intended correction should be more valgus for worse cases of arthritis.

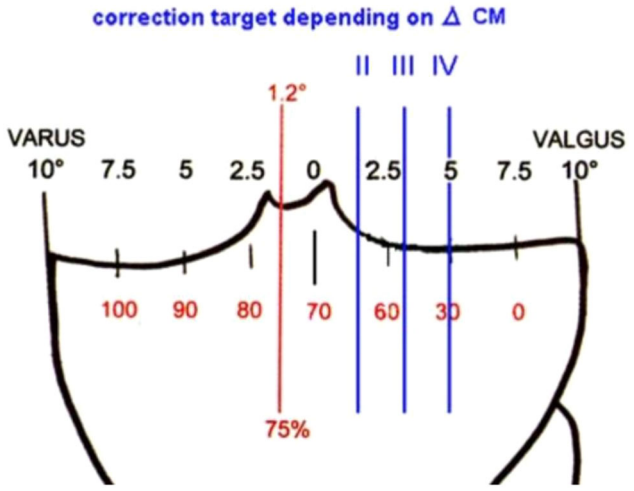

FIGURE 5 Müller and Strecker [25] proposed considering the difference between compartments before adjusting the correction.

either more or less parallel to the ground. Large corrections performed solely at the level of the proximal tibia risk placing the ankle into valgus alignment with subsequent development of ankle symptoms. A predicted clinical problem may not, however, be seen due to adaptive changes in the ankle and hindfoot except in patients with limited subtalar joint motion. Differences

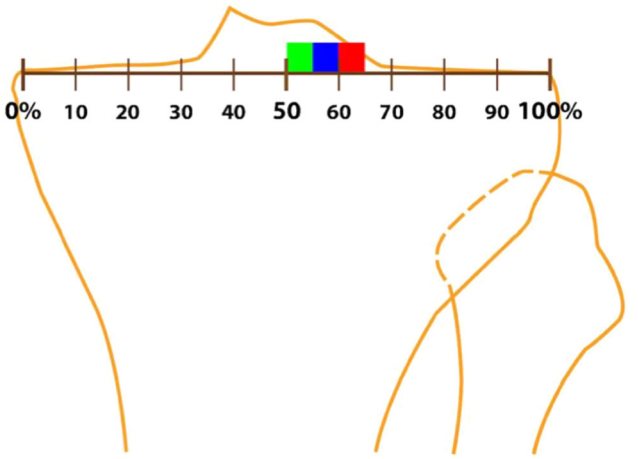

FIGURE 6 Three target zones were proposed for valgus osteotomy by Feucht et al. [9]. Indications for osteotomy (such as medial overload, cartilage repair, medial meniscal transplantation, ligamentous insufficiency) without any osteoarthritis (OA) in the green zone 50%–55%, mild OA to the blue zone 55%–60% and moderate to severe OA is targeted at the red zone 60%–65%.

related to ethnicity require more research (Grade D, Agreement 8.8 ± 0.4/9).

DISCUSSION

The most important finding in the presented consensus is demonstrating the versatility of the indications of around the knee osteotomy for the degenerative varus knee along with highlighting the essence of the planning and its technique. The sections for indication and planning comprised seven and eight questions, respectively. All questions showed a high agreement in the peer-review group. The primary outcomes of this consensus project indicate that any patient with a significant extra-articular (varus) deformity, causing intra-articular pain, and with a preserved lateral femorotibial compartment, would benefit from knee osteotomy.

The evaluation of bone deformities and joint wear should be conducted using multiple x-rays and potentially CT scans for torsional deformities or MRIs for meniscus and cartilage assessment. High-quality weight-bearing radiographs need to be taken in the correct neutral coronal position for correct alignment assessment. A strong correlation has been reported between the overlapping of the tibia and fibular head between 20° of internal to 40° of external rotation [21]. Weight-bearing radiographs are mandated because of an average alignment difference of 1.5° between weight- and nonweight-bearing films [31, 35]. The surgical procedure should ideally be performed at the deformity location to avoid creating abnormal anatomical bone and joint line obliquity. The lower limb alignment in the coronal plane has been extensively studied in healthy individuals more recently [13]. There are different

phenotypes based on the lower limb alignment and joint line orientation. A small percentage of patients of about 10% may present a neutral or valgus joint line orientation even when presenting with varus deformities [20]. These patients are more difficult to treat. However, a recent systematic review was unable to show any association between joint line orientation and clinical outcome [34].

Unloading the affected compartment is crucial, but the amount remains questionable. The general consensus was achieved considering the correction of the mechanical axis aiming 50%–68% of the width of the tibial plateau. Mechanical loading through the centre of the tibia plateau shows the loading of the medial and lateral compartments on average of 55% and 45%, respectively [36]. There is a significant correlation between the mechanical axis and the loading of the medial or lateral compartment ($R^2 = 0.878$) [18]. Moving the mechanical axis further laterally can be expected to further unload the medial compartment. Minor changes following surgery may be clinically successful. A brace test for instance may help to identify these patients [24]. Another point to note is the ankle joint alignment which is reported, following MOWHTO, to improve from preoperative valgus malalignment to postoperative neutral [15] Additionally, a recent study reported that MOWHTO increases knee joint line obliquity and results in hip adduction and ankle valgisation [16]. Furthermore, the postoperative ankle joint alignment angle was reported to significantly contribute to increased knee joint line obliquity following MOWHTO, hence should be accounted for in the preoperative planning [33].

The main limitation of this consensus is the lack of high-quality contemporaneous evidence on which to inform the discussion and subsequent statements. Much of the established science in osteotomy literature is based on outdated practice. The group was mindful that to gain realistic consensus, the questions would need to be framed in such a way that a diverse range of surgeons from around Europe and all over the world might find common ground. At times the questions were knowingly directed more towards expert opinion in areas where science was particularly short.

The consensus steering committee understood that expert opinion is inherently prone to bias. Our formal consensus process compensated for this potential weakness by involving a total of 93 specialist knee surgeons from 15 different countries across the European continent. Each of the contributing groups was independent throughout the process, following a strict methodology overseen by a consensus advisor (P. B.) who acted as a referee. A high mean score was required for a statement to be included in our consensus. Following the filtration and appraisal of all relevant scientific work, a strict methodology was pursued, which culminated in high levels of agreement on a Likert scoring system. This contributed to the production of a comprehensive, consensual document for the education of the everyday osteotomy surgeon in the most fundamental indication of their practice.

Finally, this is a guidance and not guidelines. This is not a 'how to do it' manual but a reference document. It is targeting the everyday knee surgeon with an interest in osteotomy. If this surgeon discovers through appropriate planning that this is not the everyday case they imagined, then they must seek advice or refer onwards. The guidance sets out to address the myth, the superstition and the 'bad science' by those using available science in big numbers practices. Therefore, this work may help with the decision to operate or not, how to plan, how to execute and how to rehabilitate. Additionally, the guidance provides algorithms to help manage some of the complications.

CONCLUSION

The indications of knee osteotomies for painful degenerative varus knees are broad. Part I of the consensus highlights the versatility of the procedure to address multiple scenarios with bespoke planning for each case. Deformity analysis is mandatory for defining the bone morphology, the site of the deformity and planning the correct procedure.

AUTHOR CONTRIBUTIONS

Ahmed Mabrouk, David Elson Steven Claes Vlad Predescu Raghbir Khakha Alejandro Espejo-Reina wrote the initial consensus manuscript. Steffen Schröter Ronald Van Heerwarden edited the initial draft of the consensus. Jacques Menetrey Roman Seil Roland Beker reviewed the final consensus document. Philippe Beaufils created the methods behind the present consensus. Matthieu Ollivier and Matt Dawson chaired the consensus and wrote the final manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare the following conflict of interest. Matthew Dawson: Bodycad Consultant. Steven Claes: Arthrex Consultant. Raghbir Khakha: Newclip Consultant. Steffen Schröter: Newclip, and Synthes Consultant. Ronald Van heerwarden: Newclip Consultant. Jacques Menetrey: ESSKA past president. Philippe Beaufils: Consensus director. Roman Seil: ESSKA past president. Roland Beker: ESSKA. Matthieu Ollivier: Newclip, Arthrex and Stryker Consultant. The remaining authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

All consensus data are available upon request.

ETHICS STATEMENT

No ethical approval was required for this study.

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