The Knee 41 (2023) 292–301

Contents lists available at ScienceDirect

The Knee

journal homepage:

Current clinical practice of knee osteotomy in the Netherlands

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ARTICLE INFO

Article history:
Received 5 September 2022
Revised 16 December 2022
Accepted 26 January 2023

Keywords:
Malalignment
Osteotomy
Knee
Clinical standards
Registry

ABSTRACT

Background: Realignment osteotomies is gaining popularity amongst Dutch orthopaedic surgeons. Exact numbers and used standards in clinical practice concerning osteotomies are unknown due to the absence of a national registry. The aim of this study was to investigate the national statistics of performed osteotomies, utilized clinical workups, surgical techniques, and post-operative rehabilitation standards in the Netherlands.
Method: Dutch orthopaedic surgeons, all members of the Dutch Knee Society, received a web-based survey between January and March 2021. This electronic survey contained 36 questions, subdivided into: general surgeon-related information, number of performed osteotomies, inclusion of patients, clinical workup, surgical techniques, and post-operative management.
Results: 86 orthopaedic surgeons filled in the questionnaire, of whom 60 perform realignment osteotomies around the knee. All the 60 responders (100%) perform high tibial osteotomies and 63.3% additionally perform distal femoral osteotomies, while 30% perform double level osteotomies. Discrepancies in surgical standards were reported regarding to inclusion criteria, clinical workup, surgical techniques, and post-operative strategies.
Conclusions: In conclusion, this study got more insight in knee osteotomy clinical practices as applied by Dutch orthopaedic surgeons. However, there are still important discrepancies which pleads for more standardization based on available evidence. A (inter)national knee osteotomy registry, and even more so, a (inter)national registry for joint preserving surgeries could be helpful to achieve more standardization and treatment insights. Such a registry could improve all aspects of osteotomies and its combinations with other joint-preserving interventions towards evidence for personalised treatments.

1. Introduction

Realignment osteotomies around the knee are a proven surgical treatment for unicompartmental knee osteoarthritis (OA), as this approach delays the need for a partial- or total knee arthroplasty (UKA or TKA). In the majority of patients treated with a high tibial osteotomy (HTO), a knee arthroplasty was delayed with 15 years [36]. Distal femoral osteotomy (DFO) showed a survival of 89% after ten years before revision to TKA [47]. This makes an osteotomy as joint preserving treatment very valuable for active and/or younger patients, by lowering the lifetime risk for a complex and expensive revision surgery

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https://doi.org/10.1016/j.knee.2023.01.019
0968-0160/

[4]. Modern indications for osteotomies were expanded too, as the importance of leg alignment in multiple knee pathologies was demonstrated [13,16].

This biological preservation of the knee joint by restoring the alignment is also performed by Dutch orthopaedic surgeons with unknown exact numbers. Likewise, the applied patient selection criteria, pre-operative planning techniques, surgical techniques, and post-operative rehabilitation methods lack the overview. A registry for arthroplasties is common and well accepted in the Netherlands (LROI). Unfortunately, for osteotomies such database registry is non-existent.

Several European countries prove that such registries, also containing leg realignment surgeries, could be of great value [8,11,35,39]. Overall treatment quality will increase due to more standardization and possible outliers can be detected. This will also improve research since study parameters are standardized. An important notice is that surgeons should voluntarily contribute with correct and complete data [20]. The choice of creating a new registry should therefore be not taken lightly, since there are examples of terminated registries [20]. On the contrary, a national overview with regards to lower limb osteotomies could still be of value in terms of research and patient safety.

Since there is no Dutch knee osteotomy registry, this study aimed to provide the current clinical practices as applied by orthopaedic surgeons in the Netherlands. This would provide valuable insights for research and clinical purposes, highlighting the utility of such registries.

2. Materials and methods

A nationwide electronic survey (SurveyMonkey, Momentive, San Mateo, United States) was conducted amongst 222 members of the Dutch Knee Society (DKS) between January and March 2021. All invited Orthopaedic surgeons performed knee surgeries in the Netherlands with varying experience years and clinical expertise. The survey was divided into four categories (Appendix A): (I) surgeon-related information; (II) patient selection, pre-operative workup, and pre-operative planning; (III) operative techniques and materials; (IV) postoperative management.

Responses were analysed in SPSS Statistics version 26.0.0.1 (IBM, New York, United States) using descriptive analyses, reporting means, and standard deviations. Figures were created in Prism 9 (GraphPad, San Diego, United States).

3. Results

3.1. Surgeon-related information

Amongst the 222 members of the DKS, we received 86 responses. Of the 86 responders, 60 Orthopaedic surgeons perform osteotomies around the knee. All these 60 surgeons (100%) perform HTOs, 38 surgeons (63.3%) perform distal femoral osteotomies, and 18 surgeons (30%) perform double level osteotomies. Surgeon-related information (only osteotomy performing surgeons) is displayed in Table 1.

3.2. Patient selection, pre-operative workup, and pre-operative planning

Patient selection criteria and indication for osteotomies differed between orthopaedic surgeons. Figure 1 displays the applied BMI and age exclusion criteria. The patient indications and contraindications for undergoing an osteotomy as applied by Dutch orthopaedic surgeons are summarized in Figure 2.

Table 1
Surgeon related information amongst participants of the online survey.

Topic	Answer	
Hospital level of responders	Academic centre	5 (*8.3%*)
	General hospital	43 (*71.7%*)
	Independent treatment centre	8 (*13.3%*)
	Disease specific centre	3 (*5.0%*)
	Work seeking	1 (*1.7%*)
Experience years as Orthopaedic Surgeon	0-5 years	16 (*26.7%*)
	10–15 years	15 (*25.0%*)
	5–10 years	15 (*25.0%*)
	>15 years	14 (*23.3%*)
Experience years in performing osteotomies	0–5 years	17 (*28.3%*)
	5–10 years	16 (*26.7%*)
	10–15 years	8 (*13.3%*)
	>15 years	19 (*31.7%*)
Performed osteotomies per year	Tibia	838
	Femur	262
	Double level	107
	Other	43

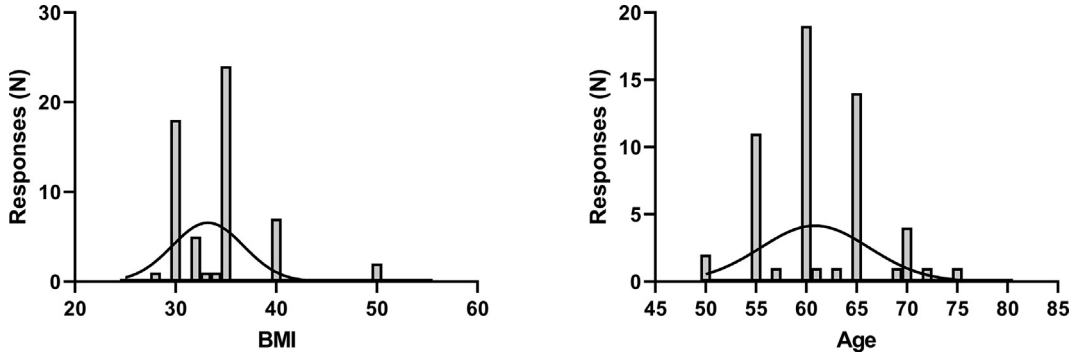

Figure 1. Applied exclusion criteria in terms of BMI and age by Dutch Orthopaedic surgeons for osteotomies around the knee. On the y-axis the number of responses (N).

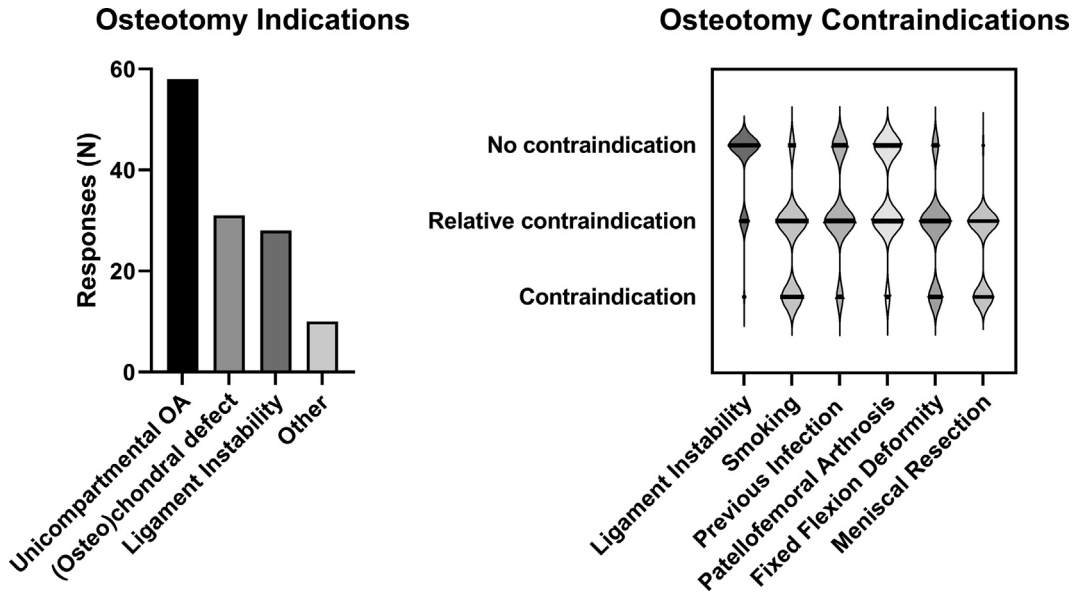

Figure 2. Indications, contraindications, relative contraindications, and no contraindications as applied by Dutch Orthopaedic surgeons for patients to undergo an osteotomy around the knee.

The responses of Dutch orthopaedic surgeons with regards to the use of diagnostic imaging are displayed in Figure 3. All surgeons obtain a whole leg radiograph (WLR) and, in most cases, accompanied with standard knee X-ray. Seven surgeons acquire an MRI scan before scheduling an osteotomy, and 2 surgeons arthroscopically assess the knee joint on beforehand.

Most surgeons (45.5%) use the Miniaci method [10] for preoperative planning of the desired osteotomy gap size. Only three surgeons (5.6%) use patient specific instrumentation (PSI) during their preparation and execution of the osteotomy (Table 2). As target correction, all surgeons desire an overcorrection in case of varus deformed malalignment, with the median at 62% Fujisawa [15] and minimum of 50% and maximum of 75%. In case of valgus deformity, surgeons choose to correct the mechanical axis towards a median Fujisawa [15] of 50% (Figure 4).

3.3. Operative techniques and materials

Dutch orthopaedic surgeons use different osteotomy approaches and techniqes (Figure 5). An open wedge HTO is the most used approach and technique in the Netherlands with 51 surgeons. Distal femoral osteotomies are performed by 30 surgeons with a medial approach and by 28 surgeons with a lateral approach.

Osteotomies are performed with anterior cruciate ligament (ACL) repairs by 21 surgeons (Figure 6). 33 surgeons perform posterior tibial slope correcting osteotomies to treat cruciate ligament deficiencies, and 10 surgeons perform rotation corrections of the lower limb. Dome osteotomies are rarely performed in the Netherlands by only two surgeons, while double level osteotomies are currently performed by 13 surgeons. Biplanar osteotomies are mostly applied proximally in HTOs.

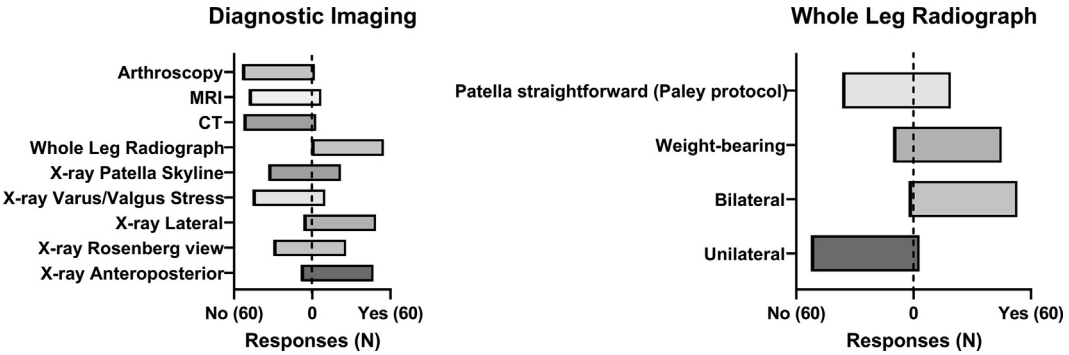

Figure 3. Responses of Dutch Orthopaedic surgeons about their use of diagnostic imaging during patient workup before indicating an osteotomy.

Table 2
Preoperative planning methods and devices as used by Dutch Orthopaedic surgeons for the preparation of osteotomies around the knee.

Topic	Answer	
Preoperative planning method	Miniaci [10]	25 (*45.5%*)
	Dugdale [49]	7 (*12.7%*)
	Coventry [6]	4 (*7.3%*)
	Paley [38]	16 (*29.1%*)
	Other	3 (*5.5%*)
Preoperative planning devices	Patient Specific Instrumentation	0 (*0.0%*)
	Dedicated software toolbox	28 (*51.9%*)
	Patient Specific Instrumentation & Dedicated software toolbox	3 (*5.6%*)
	Other	23 (*42.6%*)

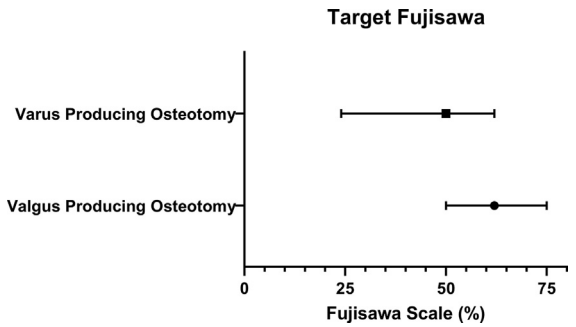

Figure 4. Targets of osteotomy corrections, for both varus producing and valgus producing osteotomies. The plot displays the median values and the ranges as responded by the Dutch Orthopaedic surgeons.

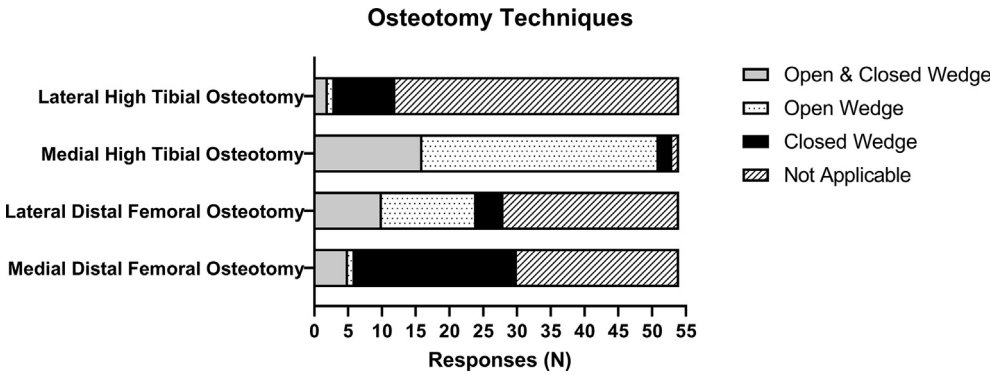

Figure 5. Osteotomy techniques used by Dutch Orthopaedic surgeons visualized per approach. On the x-axis the number of responses (N).

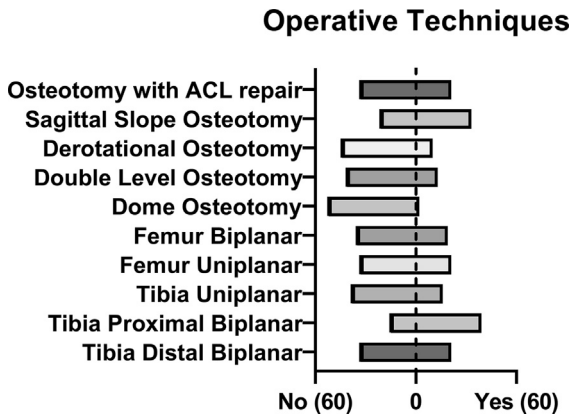

Figure 6. Surgical techniques performed by Dutch Orthopaedic surgeons in addition to the uniplanar osteotomy technique.

The Tomofix (DePuy Synthes, PA, USA) osteotomy system is the most common plate used by Dutch orthopaedic surgeons, with 46 active users (Table 3). Open wedge osteotomy gaps above 10 mm are filled by 25 surgeons, while 3 surgeons fill the gap when above 5 mm, and 5 surgeons always fill an open wedge osteotomy gap (Figure 7). 17 surgeons responded to never fill an open wedge osteotomy gap despite its size (Figure 7). The used gap filling materials in osteotomies are displayed in Figure 7.

3.4. Postoperative management

One orthopaedic surgeon responded to follow up osteotomy patients without radiographic exams, and two surgeons do not examine patients after surgery at the outpatient clinic. Only 9 surgeons use patient reported outcome measures (PROMs) for patient follow up after osteotomy (Figure 8).

3.5. Agreement Dutch orthopaedic surgeons

Figure 9 highlights topics from the five categories and arranged them based on the agreement amongst the Dutch orthopaedic surgeons. All surgeons perform osteotomies to treat unicompartmental osteoarthritis and prepare the treatment on whole leg radiographs. The surgeons had a relatively high agreement (>80%) about anteroposterior knee X-rays, patient follow up in the outpatient clinic, bilateral whole leg radiographs, and radiological follow up. Diagnostic arthroscopies are rarely used by the orthopaedic surgeons with 3.6%.

4. Discussion

This study aimed to provide an overview of the current knee osteotomy clinical practices as applied by orthopaedic surgeons in the Netherlands. Clinical practices as applied by surgeons were summarized in terms of patient indication, imaging, work-up, surgical techniques, and patient follow-up.

Most knee osteotomy performing surgeons are employed in general hospitals in the Netherlands. Together with 60 active orthopaedic surgeons around 1250 osteotomies are performed on a yearly basis. In comparison, the Swedish Arthroplasty registry reported 176 performed knee osteotomies in 2019 spread over 22 hospitals [43]. In the United Kingdom (UK) a total of 1776 osteotomy surgeries were registered in the Knee Osteotomy registry between 1 December 2014 and 1 December 2017 [39]. Orthopaedic surgeons in Germany performed 3.893 valgus producing proximal tibia and 538 varus producing distal femur osteotomies in 2013 [8]. So compared to some European countries a large number of osteotomies are performed in

Table 3
Used fixation systems of osteotomies around the knee as responded by the surgeons.

Topic	Answer	
Osteotomy Fixation System	Tomofix (Depuy Synthes)	46 (*70.8%*)
	FlexitSystem (Neosteo)	4 (*6.2%*)
	Staple fixation	4 (*6.2%*)
	Activmotion (Newclip)	3 (*4.6%*)
	Puddu plate (Arthrex)	1 (*1.5%*)
	Other	7 (*10.8%*)

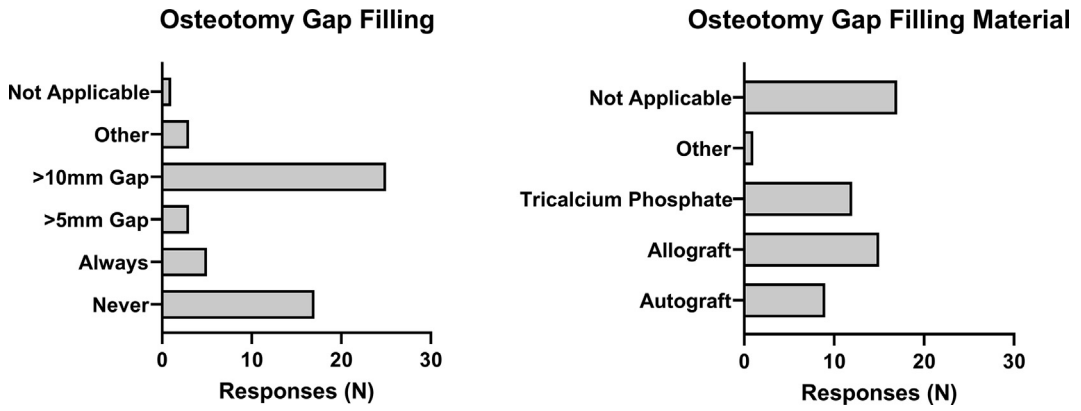

Figure 7. Osteotomy gap filling protocol and materials by Orthopaedic surgeons On the x-axis the number of responses (N).

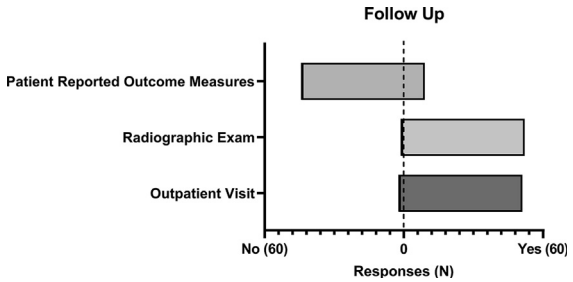

Figure 8. Patient follow up standards after undergoing osteotomy around the knee, applied by the Orthopaedic surgeons. On the x-axis the number of responses (N).

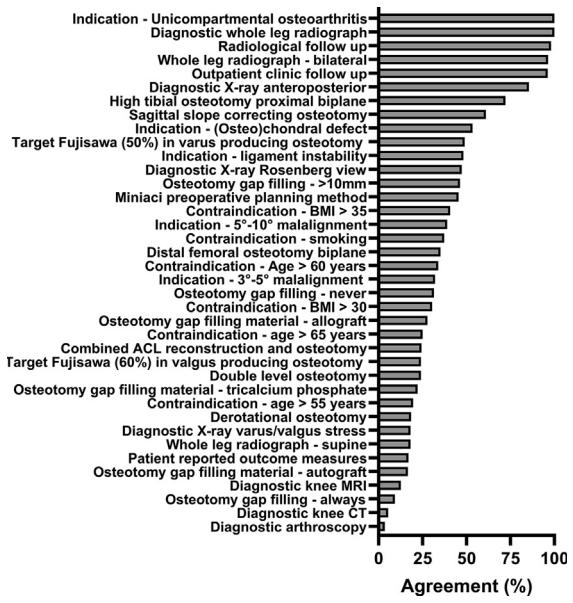

Figure 9. The agreement amongst Dutch orthopaedic surgeons in percentages (%) about the topics in knee osteotomy.

the Netherlands. Although probably not all knee osteotomies are registered by orthopaedic surgeons in the Swedish and UK registries. A solution however is the European Medical Device Regulation, enforced since the 26th of May in 2021, which ordains medical suppliers to register all patient implants. This automatically provides an overview of performed surgeries with implants in the European Union.

Interestingly, there is a dip in number of surgeons with 10–15 years of knee osteotomy experience based on the results of the current study. There was a reluctance in performing knee osteotomies as a treatment for unicompartmental knee OA since arthroplasty had gained popularity in the mid 70's [40,51]. From 2000, the benefits of open wedge HTO have been further exploited, with new fixation materials allowing for a much more refined operation technique. In contrary to a closed wedge HTO technique, an open wedge HTO prevents tibial shortening, the need for a fibular osteotomy, and future conversion to a knee arthroplasty is easier to perform. Open wedge osteotomy popularity was limited due to the need of osteotomy gap augmentation to prevent non-union or loss of correction and hardware failure. The development of locking compression plates increased the post-surgical stability of the construct and gap filling is mostly not needed anymore. The awareness of the need for joint-preserving treatment option together with more exact and extended patient indication led to the gaining popularity of knee osteotomy [24,51].

Patient indication for undergoing knee osteotomy shifted towards the more young and active patient presenting (moderate) unicompartmental knee OA [16,51,59]. So ideally the age (<60 years) and BMI (<30) of patients are low when indicated for knee osteotomy and are considered as relative contraindications [16,59]. Interestingly the indicated patients by Dutch orthopaedic surgeons vary in both BMI and age, where two surgeons do not consider BMI at all (the questionnaire's BMI was limited at 50). The potential influence of BMI and age as risk factor for treatment failure (conversion into TKA) has been investigated in many studies, with contradictory results [36]. A possible explanation is the lack of patients with extreme BMI and/or age included in certain studies [36]. Although in some studies high BMI is a potential risk factor for osteotomy non-union [26,29]. As to age for contraindication, some studies report a correlation between higher age and early revision into TKA [36]. But with careful patient selection and pre-operative functional scores age should not be a deciding factor [19]. In fact, a case series demonstrated that even elderly patients were able to return to sport after a successful HTO [31].

Knee osteotomy indication was redefined in the mid 70′s towards more moderate unicompartmental OA in light of the gained popularity of TKA [51]. Nowadays, patient selection for knee osteotomy is modernized again. HTO is increasingly performed in context of cartilage injuries, ligament instability, meniscal deficiency, and is used in combination with treatment of these knee pathologies [13,16]. A substantial number of orthopaedic surgeons in the Netherlands indicated to treat patients presenting (osteo)chondral defects and ligament instability with knee osteotomy, when this is presented as best option. The Dutch Orthopaedic Society published guidelines, indicating that patients with cartilage defects and malalignment > 5° should be treated with a combined cartilage repair and osteotomy [7].

During patient workup all Dutch orthopaedic surgeons obtain a WLR and almost all of them are bilateral views. Despite the proven importance of patient positioning and X-ray system setup, only 19 surgeons responded to employ the guidelines as proposed by Paley et al [33,34,37]. The importance of weightbearing present on WLRs for preoperative planning cannot be overstated but seems not enough since ten surgeons replied not to include weightbearing in their WLR protocol [53]. The difference between supine and standing leg alignment is significant since joint soft tissues can compress during loading, especially in the degenerated zones [14,27,41,44,57,58]. Of discussion, during preoperative planning of the desired weight-bearing line through the knee joint, there is also evidence for planning on supine radiographs for more post-surgical accuracy [46,54]. An explanation for the increased preoperative planning accuracy is the same presence of soft tissue compression in the knee joint. By transferring the weight-bearing axis towards the healthier compartment of the knee joint post-surgically, the unhealthy compartment with softer tissue gets relieved, leading to a shift in the joint line convergence angle (JLCA). This opening up of the joint is consistently observed in multiple studies and cannot be accounted for during preoperative planning, meaning that it adds up to the osteotomy inaccuracy [22,30,48,54].

Preoperative planning of knee osteotomies is of utmost importance for successful treatment outcome, which is relieve of pain in osteoarthritic knees [51]. Most Dutch orthopaedic surgeons responded to use the Miniaci method for this osteotomy planning, which is in fact the most precise technique [5,10,49]. This method considers the lower limb as one entity for correction planning, based on the hip knee angle (HKA) and Mikulicz line [10]. A hybrid option is to respect the coronal femoral an tibial geometry separately, but template the correction onto one bone using the Miniaci method [49]. Paley evolved osteotomy planning methods by applying the centre of rotation angulation (CORA) [38]. With this method the deformity location is respected unlike the doctrine of "varus in the tibia" and "valgus in the femur" [51]. Paley's method also allows for a planning of a double level osteotomy, preventing a too high joint line obliquity after surgery which could lead to early treatment failure [1,3,9,23,32,45,55]. Not respecting the CORA and postoperative joint line obliquity during preoperative planning leads to a substantial amount of undesired femoral and tibial geometries [12]. A retrospective study concluded that only 28% of varus legs was caused by an isolated proximal tibial deformity [12].

Bone void filling during open wedge osteotomy in the Netherlands has little consensus. As open wedge osteotomy techniques gained popularity from the 00′s, concerns arise about bone healing after surgery [51]. Various studies investigated the non-union rate in open wedge osteotomies [26,28,29]. Non-union still is a common complication, albeit not different between the open- and closed wedge osteotomy technique [2,26,28,29,51,52]. In fact, non-union is consistently only being correlated to obesity and smoking [26,29,51]. Although unstable hinge fractures probably induce the same problem and if observed, reoperation is needed [21,42,53,56]. Since open- and closed wedge osteotomies are clinically comparable in terms of bone-union, bone void filling during osteotomy in cases with gap size below 10 mm is not necessary [2,50]. Recently, bone void filling is sometimes being performed for another reason. Post-operative pain after open wedge osteotomy devaluates the treatment in both surgeons' and patients' perspective. One of the main reasons of postsurgical pain is presumed to be the bleeding and leakage of bone marrow from the osteotomy site [17,25]. Filling the gap with femoral head allograft and

drainage of the surgical site has proven to be effective in relieving this pain [17,25]. So filling the bone void with a femoral head allograft could be beneficial in terms of post-surgical pain and early rehabilitation [17].

Patient follow up is still an underexposed topic in knee osteotomy care. Patient indication, presurgical workup, surgical techniques, and rehabilitation protocols are common topics in literature and osteotomy summaries [16,18,51]. The Swedish osteotomy registry also excludes patient follow up [43]. In 2021 the UK Knee Osteotomy consensus Group were the first in advising standardized post-surgical follow up. They advised using KOOS and/or IKDC, Tegner score, and EuroQol 5 dimensions questionnaire (EQ-5D) [53]. However, they did not mention advised timepoints and frequency of assessing those questionnaires/scores [53]. The United Kingdom Knee Osteotomy Registry includes such standardized follow up assessments, which leads to valuable insights [39]. Considering the Dutch responses in this study, most surgeons unfortunately only include radiographic and physical examinations for follow up and no patient reported outcome measurements (PROMS).

The response rate was 86 out of 222 DKS, which suggests the idea that the current results were unable to summarize and reflect the opinions of all Dutch knee osteotomy performing orthopaedic surgeons. However, it would be likely that the most non responders were surgeons who do not perform knee osteotomies, since the questionnaire was aimed at this group. Another limitation of this study were the underexposed topics. There should be a balance in the number of questions and therefore several issues were not mentioned, like weight bearing protocols, in depth surgical osteotomy procedures, and surgical workflows when osteotomies were combined with other treatments. A joint preservation registry could solve these limitations, for instance, a committee can actively update such a registry with relevant topics in line with state-of-the-art knowledge. The same committee can add or invite orthopaedic surgeons periodically and increase the accuracy of the national mapping of joint preserving treatments.

5. Conclusions

In conclusion, this study got more insight in knee osteotomy clinical practices as applied by Dutch orthopaedic surgeons. However, there are still important discrepancies which pleads for more standardization based on available evidence. A (inter)national knee osteotomy registry, and even more so, a (inter)national registry for joint preserving surgeries could be helpful to achieve more standardization and treatment insights. Such a registry could improve all aspects of osteotomies and its combinations with other joint-preserving interventions towards evidence for personalised treatments.

Funding

This study received no funding.

Ethical approval

Ethical approval was not applicable in this study.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Our group thanks the Dutch orthopaedic surgeons for taking the time and participate in the survey.

Authors' contribution

RJH and N derived the research question. JD and HC performed the study. HC, JD, HC, RJH, and N analysed the results. All authors contributed to the writing of this manuscript and approved the final version.

References

[1] Akamatsu Y, Nejima S, Tsuji M, Kobayashi H, Muramatsu S. Joint line obliquity was maintained after double-level osteotomy, but was increased after open-wedge high tibial osteotomy. Knee Surg Sports Traumatol Arthrosc 2022;30:688–97.
[2] Angeline M. Bridging the Gap. Is Augmentation Necessary During Opening-Wedge High Tibial Osteotomy? J Bone Joint Surg 2021;103:e79.
[3] Babis GC, An KN, Chao EYS, Rand JA, Sim FH. Double level osteotomy of the knee: A method to retain joint-line obliquity clinical results. J Bone Joint Surg 2002;84:1380–8.
[4] Bayliss LE, Culliford D, Monk AP, Glyn-Jones S, Prieto-Alhambra D, Judge A, et al. The effect of patient age at intervention on risk of implant revision after total replacement of the hip or knee: a population-based cohort study. Lancet 2017;389:1424–30.
[5] Blackburn J, Ansari A, Porteous A, Murray J. Reliability of two techniques and training level of the observer in measuring the correction angle when planning a high tibial osteotomy. Knee 2018;25:130–4.
[6] Brown GA, Amendola A. Radiographic Evaluation and Preoperative Planning for High Tibial Osteotomies. Oper Tech Sports Med 2000;8:2–14.

[7] Caron JJ, Custers RJH, Emans PJ. Chirurgische behandeling van (osteo)chondrale defecten in de knie. Nederlandse Orthopaedische Vereniging 2019:1–41.
[8] Domnick C, Garcia P, Raschke MJ, Glasbrenner J, Lodde G, Fink C, et al. Trends and incidences of ligament-surgeries and osteotomies of the knee: an analysis of German inpatient records 2005–2013. Arch Orthop Trauma Surg 2017;137:989–95.
[9] Driban JB, Stout AC, Duryea J, Lo GH, Harvey WF, Price LL, et al. Coronal tibial slope is associated with accelerated knee osteoarthritis : data from the Osteoarthritis Initiative. BMC Musculoskelet Disord BMC Musculoskeletal Disorders 2016;17(299):1–7.
[10] Elson DW, Petheram TG, Dawson MJ. High reliability in digital planning of medial opening wedge high tibial osteotomy, using Miniaci's method. Knee Surg Sports Traumatol Arthrosc 2015;23:2041–8.
[11] Erivan R, Tardieu A, Villatte G, Ollivier M, Jacquet C, Descamps S, et al. Knee surgery trends and projections in France from 2008 to 2070. Orthop Traumatol Surg Res 2020;106:893–902.
[12] Feucht MJ, Winkler PW, Mehl J, Bode G, Forkel P, Imhoff AB, et al. Isolated high tibial osteotomy is appropriate in less than two-thirds of varus knees if excessive overcorrection of the medial proximal tibial angle should be avoided. Knee Surg Sports Traumatol Arthrosc 2021;29:3299–309.
[13] Fowler PJ. The importance of lower limb alignment. Sports Med Arthrosc 2007;15:1–2.
[14] Fujii T, Sato T, Ariumi A, Omori G, Koga Y, Endo N. A comparative study of weight-bearing and non-weight-bearing 3-dimensional lower extremity alignment in knee osteoarthritis. J Orthop Sci The Japanese Orthopaedic Association 2020.
[15] Fujisawa Y, Masuhara K, Shiomi S. The effect of high tibial osteotomy on osteoarthritis of the knee. An arthroscopic study of 54 knee joints. Orthop Clin North Am 1979;10:585–608.
[16] Gao L, Madry H, Chugaev DV, Denti M, Frolov A, Burtsev M, et al. Advances in modern osteotomies around the knee: Report on the Association of Sports Traumatology, Arthroscopy, Orthopaedic surgery, Rehabilitation (ASTAOR) Moscow International Osteotomy Congress 2017. J Exp Orthop J Exp Orthopaedics 2019;6.
[17] Van Genechten W, Van den Bempt M, Van Tilborg W, Bartholomeeusen S, Van Den Bogaert G, Claes T, et al. Structural allograft impaction enables fast rehabilitation in opening-wedge high tibial osteotomy: a consecutive case series with one year follow-up. Knee Surg Sports Traumatol Arthrosc 2020;28:3747–57.
[18] He M, Zhong X, Li Z, Shen K, Zeng W. Progress in the treatment of knee osteoarthritis with high tibial osteotomy: a systematic review. Syst Rev Systematic Rev 2021;10:1–10.
[19] Howells NR, Salmon L, Waller A, Scanelli J, Pinczewski LA. The outcome at ten years of lateral closingwedge high tibial osteotomy: Determinants of survival and functional outcome. Bone Jt J 2014;96B:1491–7.
[20] Hughes RE, Batra A, Hallstrom BR. Arthroplasty registries around the world: valuable sources of hip implant revision risk data. Curr Rev Musculoskelet Med Current Rev Musculoskeletal Med 2017;10:240–52.
[21] Imhoff FB, Imhoff AB. Editorial Commentary: Lateral Hinge Fracture in High Tibial Osteotomy: Risk or Annex? Arthrosc J Arthrosc Relat Surg 2018;34:3080–1.
[22] Ji W, Luo C, Zhan Y, Xie X, He Q, Zhang B. A residual intra-articular varus after medial opening wedge high tibial osteotomy (HTO) for varus osteoarthritis of the knee. Arch Orthop Trauma Surg 2019;139:743–50.
[23] Kim GW, Kang JK, Song EK, Seon JK. Increased joint obliquity after open-wedge high tibial osteotomy induces pain in the lateral compartment: a comparative analysis of the minimum 4-year follow-up outcomes using propensity score matching. Knee Surg Sports Traumatol Arthrosc 2021;29:3495–502.
[24] Li CS, Karlsson J, Winemaker M, Sancheti P, Bhandari M. Orthopedic surgeons feel that there is a treatment gap in management of early OA: International survey. Knee Surg Sports Traumatol Arthrosc 2014;22:363–78.
[25] Li S, Yang J, Watson C, Lu Q, Zhang M, Miao Z, et al. Drainage relieves pain without increasing post-operative blood loss in high tibial osteotomy: a prospective randomized controlled study. Int Orthop Int Orthopaed 2020;44:1045–6.
[26] Liska F, Haller B, Voss A, Mehl J, Imhoff FB, Willinger L, et al. Smoking and obesity influence the risk of nonunion in lateral opening wedge, closing wedge and torsional distal femoral osteotomies. Knee Surg Sports Traumatol Arthrosc 2018;26:2551–7.
[27] Marsh M, Souza RB, Wyman BT, Hellio Le Graverand MP, Subburaj K, Link TM, et al. Differences between X-ray and MRI-determined knee cartilage thickness in weight-bearing and non-weight-bearing conditions. Osteoarthritis Cartilage 2013;21:1876–85.
[28] Martin R, Birmingham TB, Willits K, Litchfield R, Lebel ME, Giffin JR. Adverse event rates and classifications in medial opening wedge high tibial osteotomy. Am J Sports Med 2014;42:1118–26.
[29] Meidinger G, Imhoff AB, Paul J, Kirchhoff C, Sauerschnig M, Hinterwimmer S. May smokers and overweight patients be treated with a medial open-wedge HTO? Risk factors for non-union. Knee Surg Sports Traumatol Arthrosc 2011;19:333–9.
[30] Micicoi G, Khakha R, Kley K, Wilson A, Cerciello S, Ollivier M. Managing intra-articular deformity in high Tibial osteotomy: a narrative review. J Exp Orthop J Exp Orthopaed 2020;7:1–10.
[31] Nakamura R, Takahashi M, Shimakawa T, Kuroda K, Katsuki Y, Okano A. High tibial osteotomy solely for the purpose of return to lifelong sporting activities among elderly patients: A case series study. Asia-Pacific J Sport Med Arthrosc Rehabil Technol 2020;19:17–21.
[32] Nakayama H, Schröter S, Yamamoto C, Iseki T, Kanto R, Kurosaka K, et al. Large correction in opening wedge high tibial osteotomy with resultant joint-line obliquity induces excessive shear stress on the articular cartilage. Knee Surg Sports Traumatol Arthrosc 2018;26:1873–8.
[33] Nguyen HC, van Egmond N, Hevesi M, Weinans H, Gielis WP, Custers RJH. A new protocol for obtaining whole leg radiographs with excellent reproducibility. J Cartil Jt Preserv 2022;2:100042.
[34] Nguyen HC, Gielis WP, van Egmond N, Weinans H, Slump CH, Sakkers RJB, et al. The need for a standardized whole leg radiograph guideline: The effects of knee flexion, leg rotation, and X-ray beam height. J Cartil Jt Preserv 2021;1:100022.
[35] Niinimäki TT, Eskelinen A, Ohtonen P, Junnila M, Leppilahti J. Incidence of osteotomies around the knee for the treatment of knee osteoarthritis: A 22-year population-based study. Int Orthop 2012;36:1399–402.
[36] Ollivier B, Berger P, Depuydt C, Vandenneucker H. Good long-term survival and patient-reported outcomes after high tibial osteotomy for medial compartment osteoarthritis. Knee Surg Sports Traumatol Arthrosc 2021;29:3569–84.
[37] Paley D. Radiographic Assessment of Lower Limb Deformities. Princ Deform Correct 2002:31–60.
[38] Paley D. Normal Lower Limb Alignment and Joint Orientation. Princ Deform Correct. Berlin, Heidelberg: Springer Berlin Heidelberg; 2002. p 1–18.
[39] Palmer H, Elson D, Baddeley T, Porthouse A. United Kingdom Knee Osteotomy Registry: The First Annual Report 2018 For. 21. 2018.
[40] Patel NG, Waterson HB, Phillips JRA, Toms AD. 50 Years of Total Knee Arthroplasty. Bone Jt 2019;360(8):3–7.
[41] Paternostre F, Schwab PE, Thienpont E. The difference between weight-bearing and non-weight-bearing alignment in patient-specific instrumentation planning. Knee Surg Sports Traumatol Arthrosc 2014;22:674–9.
[42] Van Raaij TM, Brouwer RW, De Vlieger R, Reijman M, Verhaar JAN. Opposite cortical fracture in high tibial osteotomy: Lateral closing compared to the medial opening-wedge technique. Acta Orthop 2008;79:508–14.
[43] Robertsson O, W-Dahl A, Lidgren L, Sundberg M. Annual Report 2020: Swedisch Knee Arthroplasty Register. 2020.
[44] Schoenmakers DAL, Feczko PZ, Boonen B, Schotanus MGM, Kort NP, Emans PJ. Measurement of lower limb alignment: there are within-person differences between weight-bearing and non-weight-bearing measurement modalities. Knee Surg Sports Traumatol Arthrosc 2017;25:3569–75.
[45] Schuster P, Geßlein M, Schlumberger M, Mayer P, Mayr R, Oremek D, et al. Ten-Year Results of Medial Open-Wedge High Tibial Osteotomy and Chondral Resurfacing in Severe Medial Osteoarthritis and Varus Malalignment. Am J Sports Med 2018;46:1362–70.
[46] Shin KH, Jung JK, Nam JJ, Jang KM, Han SB. Preoperative Supine Radiographs Are More Accurate Than Standing Radiographs for Preoperative Planning in Medial Open-Wedge High Tibial Osteotomy. Arthrosc J Arthrosc Relat Surg 2020;36:1655–64.
[47] Shivji FS, Foster A, Risebury MJ, Wilson AJ, Yasen SK. Ten-year survival rate of 89% after distal femoral osteotomy surgery for lateral compartment osteoarthritis of the knee. Knee Surg Sports Traumatol Arthrosc 2021;29:594–9.

[48] Sim JA, Na YG, Lee BK, Lee BH. Alignment changes after open-wedge high tibial osteotomy result in offloading in the patellofemoral joint: a SPECT/CT analysis. Knee Surg Sports Traumatol Arthrosc 2022;30:437–46.
[49] Sivertsen EA, Vik J, Meland ASV, Nerhus TK. The Dugdale planning method for high tibial osteotomies underestimates the correction angle compared to the Miniaci method. Knee Surg Sports Traumatol Arthrosc 2021.
[50] Slevin O, Ayeni OR, Hinterwimmer S, Tischer T, Feucht MJ, Hirschmann MT. The role of bone void fillers in medial opening wedge high tibial osteotomy: a systematic review. Knee Surg Sports Traumatol Arthrosc 2016;24:3584–98.
[51] Smith JO, Wilson AJ, Thomas NP. Osteotomy around the knee: Evolution, principles and results. Knee Surg Sports Traumatol Arthrosc 2013;21:3–22.
[52] Smith TO, Sexton D, Mitchell P, Hing CB. Opening- or closing-wedged high tibial osteotomy: A meta-analysis of clinical and radiological outcomes. Knee 2011;18:361–8.
[53] Snow M, Jermain P, Mandalia V, Murray J, Khakha R, McNicholas M, et al. A 2021 consensus statement on osteotomies around the knee by the UK Knee Osteotomy consensus Group (KOG). Knee 2021;33:73–83.
[54] So SY, Lee SS, Jung EY, Kim JH, Wang JH. Difference in joint line convergence angle between the supine and standing positions is the most important predictive factor of coronal correction error after medial opening wedge high tibial osteotomy. Knee Surg Sports Traumatol Arthrosc 2020;28:1516–25.
[55] Song JH, Il BS, Kim JM, Lee BS. What Is An Acceptable Limit of Joint-Line Obliquity After Medial Open Wedge High Tibial Osteotomy? Analysis Based on Midterm Results. Am J Sports Med 2020;48:3028–35.
[56] Takeuchi R, Ishikawa H, Kumagai K, Yamaguchi Y, Chiba N, Akamatsu Y, Saito T. Fractures around the lateral cortical hinge after a medial opening-wedge high tibial osteotomy: A new classification of lateral hinge fracture. Arthrosc J Arthrosc Relat Surg 2012;28:85–94.
[57] Yazdanpanah O, Karimi Mobarakeh M, Nakhaei M, Baneshi MR, Karimi Mobarakeh M. Comparison of Double and Single Leg Weight-Bearing Radiography in Determining Knee Alignment. Arch Bone Jt Surg 2017;174:174–80.
[58] Zahn RK, Renner L, Perka C, Hommel H. Weight-bearing radiography depends on limb loading. Knee Surg Sports Traumatol Arthrosc. 2018;1–7.
[59] Zampogna B, Vasta S, Papalia R. Patient Evaluation and Indications for Osteotomy Around the Knee. Clin Sports Med 2019;38:305–15.