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Surgical Technique

Accelerometer-Navigated Revision Total Knee Arthroplasty: A Technique for Successful Gap Balancing

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ABSTRACT

Accelerometer-based navigation (OrthAlign) is the first computer-assisted surgical navigation system approved for use in the setting of revision total knee arthroplasty (TKA) in the United States. The senior author has used this technology in the revision setting for several years and developed the individualized, reproducible technique. The 4 goals during revision TKA are to (1) gain adequate exposure for the safe explanation of prior implants, (2) address any resultant bone loss, (3) restore the joint line via distal femur metal augmentation, and (4) ensure adequate stability through gap-balancing techniques and increasing the constraint of the revision implants as needed. This technique guide illustrates how accelerometer-based navigation (OrthAlign) can achieve these goals in the revision TKA setting.

Introduction

Computer-assisted surgical (CAS) navigation has been increasingly used in primary total knee arthroplasty (TKA) over the past 10 years [1]. This type of surgery involves using an intraoperative device with an interface for data entry that provides real-time reflexive feedback regarding overall alignment and implant positioning. These CAS navigation systems have been associated with significantly improved TKA postoperative alignment and implant positioning [2-4]. However, compared to conventional instrumentation, patient-reported outcomes and revision rates have yielded more heterogeneous results [5-8]. Given that CAS navigation involves innovative technology compared to conventional manual TKA instrumentation alone, sufficient long-term data are yet to be established.

Accelerometer-based navigation systems (such as OrthAlign) have emerged in the field of CAS with great enthusiasm due to their ease of use, portability (ie, no need for a large computer tower intraoperatively), and avoidance of the need for added reference pins for tracker arrays. These accelerometer-based CAS systems are superior in postoperative coronal plane alignment compared to conventional instrumentation [5-8] and equivalent to conventional infrared camera navigation, patient-specific custom cutting guides, or robotic guidance [9,10].

Importantly, most of these CAS navigation systems are only approved by the Food and Drug Administration for primary TKA. Accelerometer-based navigation (OrthAlign) is approved for computer navigation in primary and revision TKA settings [11]. The senior author has been using this technology in the revision setting for several years and developed the individualized, reproducible technique for use [12]. The 4 goals during revision TKA are to (1) gain adequate exposure for the safe explanation of prior implants, (2) address any resultant bone loss, (3) restore the joint line via distal femur metal augmentation, and (4) ensure adequate stability through gap-balancing techniques and increasing the constraint of the revision implants as needed. While it can also be used in 1-component TKA revisions, the following technique guide illustrates how accelerometer-based navigation (OrthAlign) can be used to achieve these goals in the 2-component revision TKA setting.

Surgical technique

Approach and explantation

The procedure begins by performing the standard medial parapatellar approach using the lateralmost longitudinal skin incision

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Figure 1. Magnetic augment buttons from a revision total knee arthroplasty set may be placed on the paddles of the OrthAlign gap tensioner. These magnetic buttons serve to account for planned augments or medial/lateral asymmetry based on distal femoral or proximal tibial bone cuts. In this case, a 5-mm button was placed on the lateral side to account for the +5-mm lateral distal femur asymmetric bone resection.

from prior surgeries. After raising full-thickness skin flaps, a medial parapatellar arthrotomy is made to gain exposure to the intra-articular space. An extended medial release is then performed via electrocautery elevation of the periosteum and deep medial collateral ligament to facilitate tibial external rotation. Generous synovectomy and scar debridement are performed to restore the medial and lateral gutters around prior implants while being careful not to injure the collateral ligaments. Finally, the polyethylene is removed to facilitate exposure. In most cases, these steps collectively negate the need for "extensile" exposure techniques. The existing implants are then removed in a manner based on surgeon preference. Care must be taken to minimize iatrogenic removal of bone. Importantly, adequate exposure must have been obtained to allow sufficient tibial external rotation and anterior subluxation for the tibial tray to clear the distal femur during removal. After the femoral and tibial components are extracted, all residual cement is carefully removed as well.

Establishing the extension gap

With all prior implants and cement removed, the surgeon may proceed with preparing the remaining host bone for revision components. This begins with sequentially reaming the tibia and femoral intramedullary canals to an appropriate depth and adequate endosteal fit for planned cementless stem fixation.

Preparation begins on the tibia first. The final intramedullary reamer is left in place for anatomic axis reference, and an appropriately sized baseplate and offset are determined. Freshened bone cuts are performed using standard intramedullary cutting guides to ensure final implant contact with healthy, viable bone. Generally, 2 areas of zonal fixation are encouraged in the revision TKA setting to provide a secure fixation [13]. This may require asymmetric medial and lateral bone resection, which can be later replaced using metal augments. Additional preparation for metaphyseal sleeve/cone fixation (authors' preference) may be performed based on surgeon preference as needed to obtain appropriate metaphyseal fixation.

On the femur side, the final intramedullary reamer is replaced within the intramedullary canal to serve as an anatomic axis reference. It is the authors' preference to use diaphyseal-engaging cementless stems. As such, deviation from the implant-manufactured 6° anatomic valgus angle cannot be changed (ie, a distal femur cut is performed at 6° of anatomic valgus). If a surgeon prefers short, fully cemented stems, it is possible to change coronal alignment cuts. In either case, as in the tibia, this may require asymmetric cuts along the medial and lateral sides of the distal femur to ensure direct implant-bone contact. Importantly, the senior author prefers to use a minimum of 5 mm distal femur augmentation on both the medial and lateral sides. This helps to re-establish the native joint line and avoids the tendency of raising the joint line in the revision setting. Additional asymmetric distal femur cuts can easily be accounted for by using larger augments as needed (ie, final augments of 5 mm medial and 10 mm lateral).

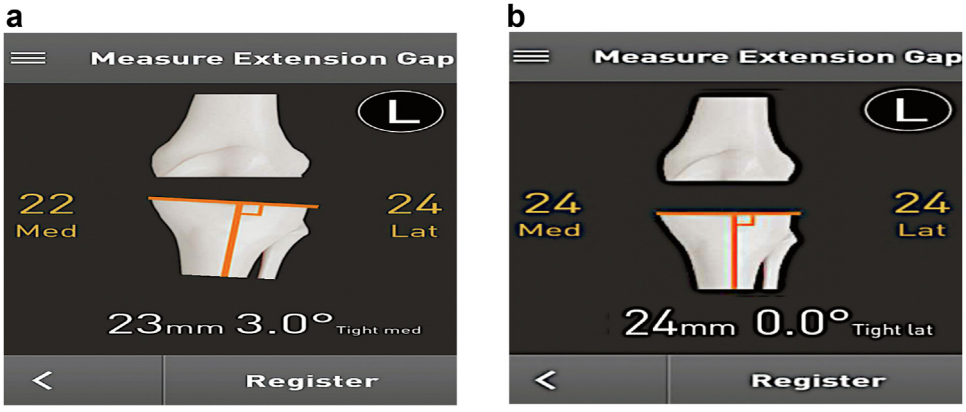

Figure 2. (a) The OrthAlign gap tensioner displayed that the initial extension gap was asymmetric with the medial side being 2-mm tighter than the lateral side. Therefore, an additional medial release was performed for soft tissue titration. (b) The OrthAlign gap tensioner was reinserted after performing additional medial release, demonstrating equal medial and lateral extension gaps.

Distal femur augments	5mm (10mm augment laterally)*
Distal femur component	9mm
Tibial tray and polyethylene	10mm
Total	**24mm**

Figure 3. To match the prosthesis to the extension gap, this graph demonstrates the breakdown of each contributing variable. * Of note, a 10-mm lateral augment was used due to an asymmetric distal femur cut; therefore, a 5-mm magnetic trial augment was placed on the lateral aspect of the gap tensioner paddle to provide symmetry.

With fresh distal femoral and tibial cuts, the knee is brought into full extension, and the OrthAlign Lantern gap tensioner is inserted and distracted by a torque-limited driver. The senior author also uses a nontorque-limiting driver for final added tension (being careful not to overdistract and cause iatrogenic ligamentous injury). In cases of asymmetric distal femoral or tibial augments, off-label use of magnetic trial augments may be used on the gap tensioner paddles to account for asymmetric distal femur cuts or asymmetric tibial resection (Fig. 1). The initial medial and lateral extension gaps are determined (Fig. 2a). Additional soft tissue releases are used as needed. The gap tensioner is reinserted to ensure symmetrical medial and lateral extension gaps after any soft tissue releases (Fig. 2b). Importantly, this must then be registered into the OrthAlign Lantern interface screen, as the flexion gap will be reflected relative to these registered values at a later point in the case.

Once the extension gap has been balanced and established, the surgeon must determine the most appropriate initial implant construct to symmetrically fill the established extension gap. This requires a thorough knowledge of the implant being used. For this case, a 5-mm medial distal femoral augment and a 10-mm lateral distal femoral augment were planned. For calculation purposes to fill the extension gap, 5 mm of distal femoral augment is added to 9 mm of distal femoral component thickness for a total of 14 mm construct thickness originating from the femoral side. This leaves 10 mm of construct thickness from the tibia (24 mm −14 mm = 10 mm) (Fig. 3).

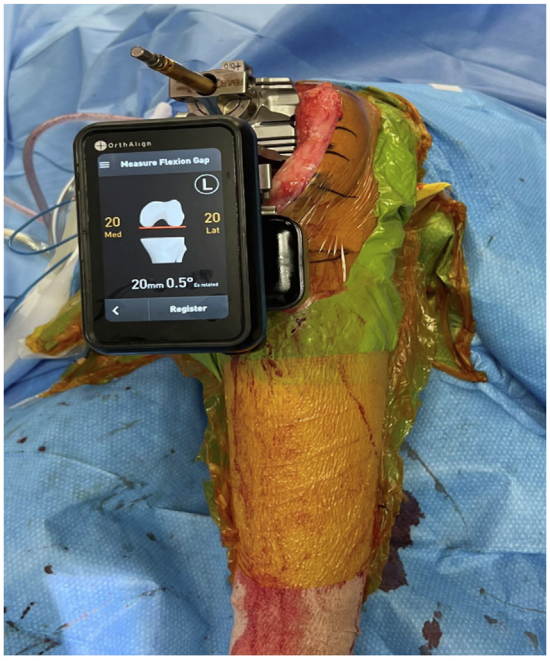

Figure 4. With the 4-in-1 distal femur cutting guide in place, the OrthAlign Lantern gap tensioner is inserted to assess the flexion gap. The 4-in-1 cutting guide can be internally or externally rotated until the medial and lateral flexion gaps are symmetric (as shown). Once the ideal symmetric rotation has been established, the guide is carefully pinned in place. Note the posterior capture thickness when determining the flexion gap.

Establishing the flexion gap

With an established balanced extension gap, the knee is brought into 90° of flexion to measure the flexion gap. The final femur intramedullary reamer is reinserted into the femoral canal. An appropriately sized 4-in-1 cutting guide is slid over the intramedullary reamer. If needed, any necessary sizing change or offset

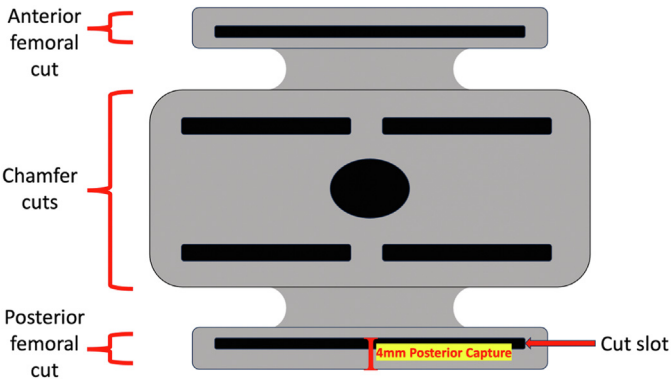

Figure 5. This revision knee system has a 4-in-1 cutting guide with a 4-mm posterior capture which must be accounted for in determining the appropriately sized implant to fill the flexion gap.

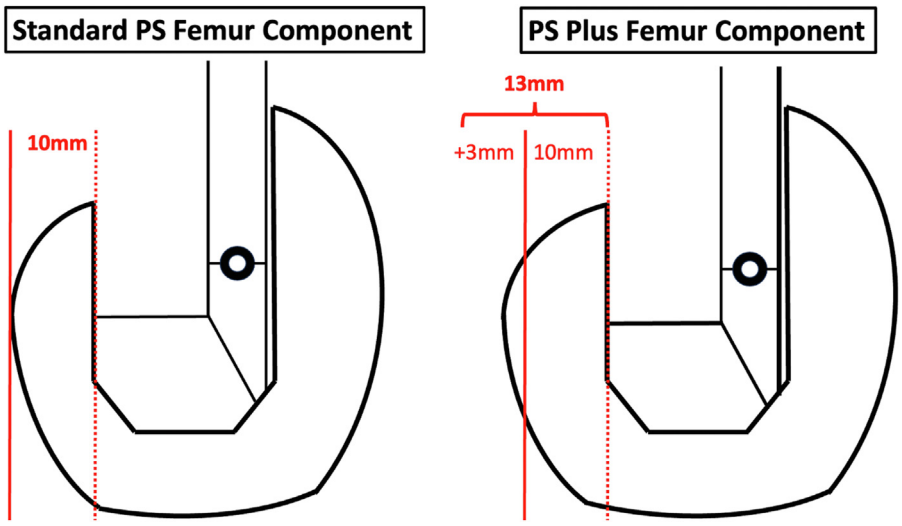

Figure 6. A pictorial representation of the standard posterior component thickness for a posterior stabilized (PS) femur component compared to a "plus" sized implant.

can be dialed in at this time. Once satisfied, the appropriate size and offset 4-in-1 cutting guide is placed over the intramedullary reamer followed by the insertion of the OrthAlign Lantern gap tensioner. The surgeon must ensure the gap tensioner paddles are sitting flush on the proximal tibia and the posterior aspect of the 4-in-1 guide, not on the posterior femoral bone. The gap tensioner is distracted using the same torque-limiting handle as before, followed by careful additional distraction as indicated. After the paddles have been distracted, the 4-in-1 cutting guide can be manually rotated while visualizing the live changes in the medial and lateral flexion gaps on the OrthAlign Lantern screen (Fig. 4). Before pinning the 4-in-1 cutting guide in place, the surgeon should determine the appropriate implant to fill the flexion gap in case any changes are required to the cutting guide size or position. This requires a thorough understanding of the cutting guide, the thickness of the posterior condyle implant being used, and anterior vs posterior referencing. For example, there may be a 4-mm thickness of the posterior capture on the 4-in-1 block (Fig. 5) and a 10-mm posterior condyle implant thickness (Fig. 6). In this case, when accounting for the 4-mm posterior capture thickness, the flexion gap numbers should ideally be 6 mm or 9 mm (for plus femur sizes; Fig. 6) larger than the planned tibial construct thickness to ensure that the posterior condyle will fill the remaining flexion gap space (Fig. 7). In systems with 4-in-1 guides with uncaptured posterior condyle cuts, the visualized flexion gap measurement on the Lantern screen is the true flexion gap size that must be filled with posterior condylar implant thickness.

Since no bone cuts have been made yet through the 4-in-1 cut block, small adjustments can be easily performed if the 4-in-1 block needs to be posteriorized, upsized, or rotated as needed for a symmetrically filled flexion gap. Again, thorough knowledge of the company-specific instrumentation and implants used cannot be understated. Small increases in the flexion gap can be made with company-specific implants (Fig. 6) or by upsizing and/or posteriorizing the femoral component. Larger adjustments may require changing the polyethylene thickness or augmenting the tibial

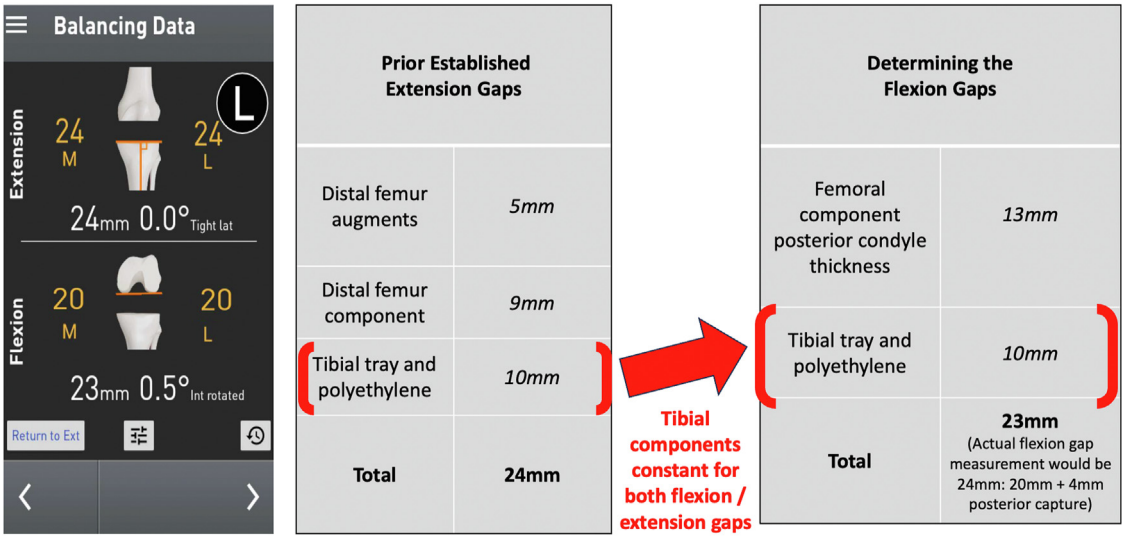

Figure 7. A depiction of calculations made when determining the most appropriate implants to fill the flexion and extension gaps. Note the 1-mm discrepancy between the measured flexion gaps (Fig. 4), taking into account the 4-mm posterior capture, and the planned construct thickness posteriorly. In general, the flexion gap can accommodate 1 mm more construct thickness.

Figure 8. A final check with OrthAlign paddles placed directly on bone after completing posterior bone cuts using the 4-in-1 cutting guide.

baseplate. However, this requires reflexive changes to the extension gap components which may result in the necessary raising of the joint line in very limited circumstances. Once the surgeon determines the most appropriate implant configuration to ensure symmetrical filled extension and flexion gaps (Fig. 7), the block is pinned, and posterior bone cuts are made through the 4-in-1 cutting guide.

Adequate bone cuts must ensure direct prosthesis contact posteriorly with the bone to ensure that final implant rotation is consistent with the rotation determined with the gap tensioner. Once all bone cuts have been completed, trial implants can be placed. Before trialing, for surgeons new to using OrthAlign Lantern, the senior author recommends performing a final check before placing trial implants to build confidence in the device's accuracy. With the 4-in-1 cutting guide removed, the OrthAlign Lantern may be reinserted directly onto the tibial and posterior condylar bone. If additional or asymmetric posterior condylar resection was performed through the 4-in-1 cutting guide, surgeons must account for the thickness of the posterior augments to the paddles (via magnetic augment buttons applied similarly to Fig. 1). Using the Lantern summary screen, both the extension and flexion gaps can be displayed for comparative reference and to confirm appropriate final implants (Fig. 8).

Trialing and final implantation

Trial implants are placed with appropriate augments and the knee is brought through range of motion and surgeon assessment of ligamentous stability. The senior author has seldom experienced a case in which any further adjustments are required; at most, small changes in polyethylene thickness. Once satisfied, trial implants are removed, and final implants are cemented into place as indicated (Fig. 9).

Discussion

OrthAlign offers computer-assisted navigation technology that, in the hands of an experienced surgeon, may serve useful in the setting of 2-component revision TKA. Importantly, it allows for precise, objective gap-balancing with real-time feedback. A thorough understanding of company-specific implant sizing allows for projected final implants to be quickly determined. Thus, this technology can also help negate the need for multiple rounds of trialing to achieve subjective, surgeon-perceived gap balancing.

Some major orthopaedic adult reconstruction implant companies offer "classic" mechanical tensiometer devices that generally show a mechanical measurement of gap height, thus being purportedly similar to the functionality of OrthAlign. However, an advantage of OrthAlign is that it can demonstrate, in real-time, precise measurements of isolated medial and lateral gap heights and angular deformities at the extension and flexion gap level that would clue the surgeon into performing soft tissue releases should they choose to do so. As an added benefit, OrthAlign has no upfront capital cost. There are undoubtedly advantages to purchasing on a per-case basis for OrthAlign compared to the upfront large capital expenditure for a commercially available robot plus the per-case robotic costs (ie, disposables). The costs for OrthAlign vary based on hospital-specific contract pricing; however, the authors and their hospital administrators have found these to be financially equivalent to the per-case cost for robotic disposables (ie, specialized robot drapes, bone pins, checkpoints, and visualization discs). As a further delineating benefit over robotic-assisted TKA, OrthAlign allows the surgeon to choose their revision TKA implant company independent of the technology used. Without the requirement to use pins and arrays in the femur and tibia, stem fixation choice is also at the surgeon's discretion, compared to robotic designs where robotic pins may interfere with long-stemmed trials and implants.

OrthAlign is not an absolute requirement for successfully performing revision TKA. Conventional instrumentation and even

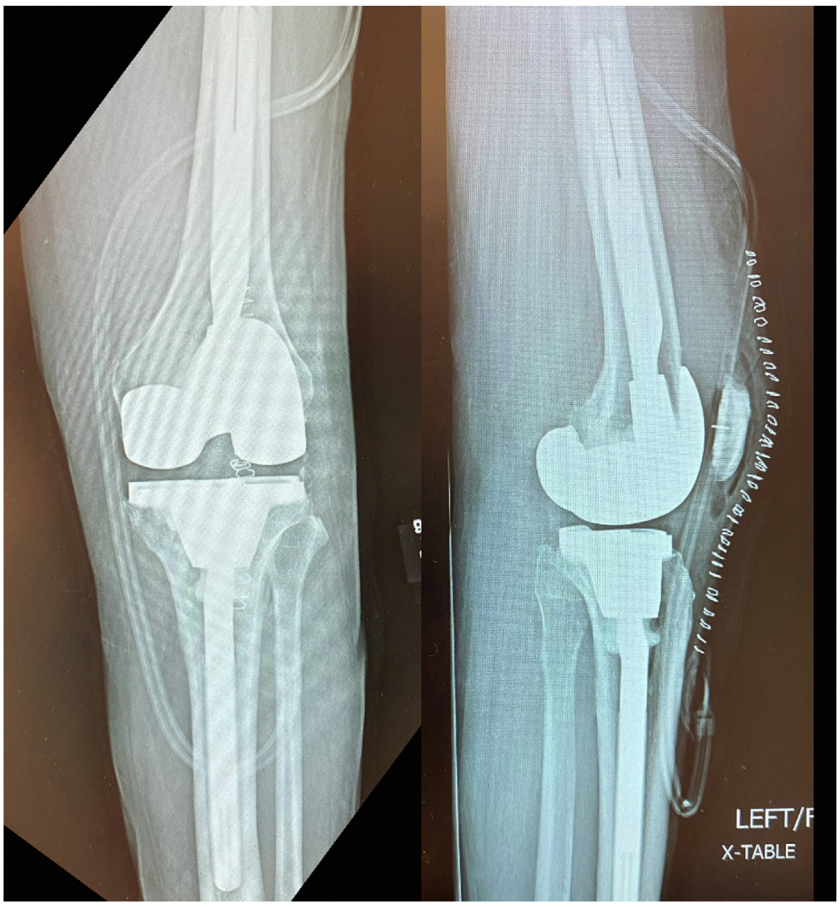

Figure 9. Final implants demonstrating appropriate revision TKA construct with diaphyseal engaging stem fixation and utilization of a tibial metaphyseal cone.

robotic-assisted [14] revision TKA serve as alternative techniques. However, this technique guide demonstrates a novel approach to using OrthAlign for revision TKA compared to its typical intended use of primary TKA. From the authors' experience and perspective, OrthAlign can serve as a useful tool to fill the commonly encountered asymmetric gap imbalances in the revision setting. Anecdotally, a learning curve should be expected for the first 5 to 10 cases to maximize familiarity with the device. After this, the surgeon may expect increased confidence and a decreased need for repeated trialing. As emphasized, this technique requires a thorough knowledge and understanding of the surgeon's preferred implant company sizes for success.

Summary

Preventing gap imbalance is a technically demanding goal in the setting of revision TKA. From the authors' perspective, OrthAlign accelerometer-based navigation technology allows for precise, objective gap-balancing feedback in the revision setting. This technology negates the need for multiple rounds of trialing to achieve subjective, surgeon-perceived gap balancing. Furthermore, it leaves the autonomy of implant determination in the hands of the surgeon and can be used with any company's revision TKA system. A thorough knowledge of company-specific implant systems is necessary for success. With adequate surgical planning and a short-lived learning curve, the authors find that using OrthAlign Lantern can be valuable in any revision arthroplasty surgeon's armamentarium. Future research is needed to investigate the effects on survivorship and the cost of using this technology in the revision TKA setting.

Conflicts of interest

Dr. Purcell serves as a paid consultant to OrthAlign. Otherwise, he and Dr. Wells certify that they have no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) or other financial disclosures that might pose a conflict of interest in connection with the submitted article.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2024.101510.

Disclosure

The opinions and/or assertions contained herein are the private views of the authors and are not to be construed as reflecting the official position or views of William Beaumont Army Medical Center, the Department of the Army, the Department of Defense, or the US Government.

CRediT authorship contribution statement

Matthew E. Wells: Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Richard L. Purcell:** Writing – review & editing, Writing – original draft, Supervision.

References

[1] Antonios JK, Korber S, Sivasundaram L, Mayfield C, Kang HP, Oakes DA, et al. Trends in computer navigation and robotic assistance for total knee arthroplasty in the United States: an analysis of patient and hospital factors. Arthroplast Today 2019;5:88–95. https://doi.org/10.1016/j.artd.2019.01.002.

[2] Petursson G, Fenstad AM, Gøthesen Ø, Dyrhovden GS, Hallan G, Röhrl SM, et al. Computer-assisted compared with conventional total knee replacement: a multicenter parallel-group randomized controlled trial. J Bone Joint Surg Am 2018;100:1265–74. https://doi.org/10.2106/JBJS.17.01338.

[3] de Steiger RN, Liu YL, Graves SE. Computer navigation for total knee arthroplasty reduces revision rate for patients less than sixty-five years of age. J Bone Joint Surg Am 2015;97:635–42. https://doi.org/10.2106/JBJS.M.01496.

[4] MacDessi SJ, Jang B, Harris IA, Wheatley E, Bryant C, Chen DB. A comparison of alignment using patient specific guides, computer navigation and conventional instrumentation in total knee arthroplasty. Knee 2014;21:406–9. https://doi.org/10.1016/j.knee.2013.11.004.

[5] Fu Y, Wang M, Liu Y, Fu Q. Alignment outcomes in navigated total knee arthroplasty: a meta-analysis. Knee Surg Sports Traumatol Arthrosc 2012;20:1075–82. https://doi.org/10.1007/s00167-011-1695-6.

[6] Rhee SJ, Kim HJ, Lee CR, Kim CW, Gwak HC, Kim JH. A comparison of long-term outcomes of computer-navigated and conventional total knee arthroplasty: a meta-analysis of randomized controlled trials. J Bone Joint Surg Am 2019;101:1875–85. https://doi.org/10.2106/JBJS.19.00257.

[7] Roberts TD, Clatworthy MG, Frampton CM, Young SW. Does computer assisted navigation improve functional outcomes and implant survivability after total knee arthroplasty? J Arthroplasty 2015;30(9 Suppl):59–63. https://doi.org/10.1016/j.arth.2014.12.036.

[8] Xie C, Liu K, Xiao L, Tang R. Clinical outcomes after computer-assisted versus conventional total knee arthroplasty. Orthopedics 2012;35:e647–53. https://doi.org/10.3928/01477447-20120426-17.

[9] Bouché PA, Corsia S, Dechartres A, Resche-Rigon M, Nizard R. Are there differences in accuracy or outcomes scores among navigated, robotic, patient-specific instruments or standard cutting guides in tka? A network meta-analysis. Clin Orthop Relat Res 2020;478:2105–16. https://doi.org/10.1097/CORR.0000000000001324.

[10] Nam D, Weeks KD, Reinhardt KR, Nawabi DH, Cross MB, Mayman DJ. Accelerometer-based, portable navigation vs imageless, large-console computer-assisted navigation in total knee arthroplasty: a comparison of radiographic results. J Arthroplasty 2013;28:255–61. https://doi.org/10.1016/j.arth.2012.04.023.

[11] Kavlock KD. OrthAlign FDA approval. Silver Spring, MD: U.S. Food & Drug Administration (FDA); 2017.

[12] Purcell R. Achieving stability in revision TKA – Lantern® balance live surgery demonstration. Oakland, CA: VuMedi.com; 2024.

[13] Morgan-Jones R, Oussedik SI, Graichen H, Haddad FS. Zonal fixation in revision total knee arthroplasty. Bone Joint J 2015;97-B:147–9. https://doi.org/10.1302/0301-620X.97B2.34144.

[14] MacAskill M, Blickenstaff B, Caughran A, Bullock M. Revision total knee arthroplasty using robotic arm technology. Arthroplast Today 2022;13:35–42. https://doi.org/10.1016/j.artd.2021.11.003.