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RESEARCH ARTICLE

Revision Total Knee Arthroplasty Using an Implant-Agnostic, Joint-Line Based, Gap-Balanced Technique

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ABSTRACT

Purpose: Instability is a significant cause of failure following revision total knee arthroplasty and results in the lowest patient satisfaction. This study validates, under controlled cadaveric parameters, a joint-line based, gap-balancing technique for performing revision total knee arthroplasty using an implant-agnostic workflow.

Materials and Methods: A cadaveric feasibility study was completed with eight lower extremities previously prepared for total knee arthroplasty in kinematic alignment undergoing revision total knee arthroplasty to mechanical alignment with a joint-line based, gap-balanced workflow. A step-by-step guide for this technique was documented and performed, and accuracy of the approach was quantified in all cases.

Results: After bone preparation, the measured gaps were all within 1mm of the desired measurement (medial extension 0.38mm, lateral extension 0.63mm, medial flexion 0.75mm, and lateral flexion 0.25mm), accepting the pre-calculated implant and augment sizes. There were no adjustments needed to bone cuts or soft tissues in any specimen. Of interest, 10mm posterolateral augments were required in all specimens.

Conclusions: The technique described in this study showed promising accuracy in a series of cadaveric specimens. With additional clinical testing, this approach to revision total knee arthroplasty could prove to reduce the need for re-revision and improve patient satisfaction.

Keywords: knee osteoarthritis, instability, revision knee replacement, revision total knee arthroplasty.

Introduction

Despite the rising success of total knee arthroplasty (TKA), absolute volumes of revision total knee arthroplasty (RTKA) are increasing in the United States with an estimated rise of 149% by 2040[1,2]. Patients undergoing RTKA often experience chronic complications and repeated revision procedures leading to increased in-hospital mortality, longer lengths of stay, and higher total charges compared to primary TKA patients[3]. The leading causes of RTKA are aseptic loosening, infection, and instability[4–6]. However, instability is at a high risk of underreporting with some literature suggesting it could account for up to 45% of midterm failures[7]. Multiple studies have shown the lowest patient satisfaction rates in aseptic cases with instability[8]. In this clinical scenario there is a high rate of failure for recurrent instability, which according to the 2024 American Joint Replacement Registry (AJRR), accounts for 57% of all re-revisions when the primary indication for revision was instability[6]. Therefore, performing RTKA in a manner that minimizes instability and improves patient satisfaction is critical.

Each revision knee replacement presents a unique combination of ligament laxity, bone loss, and contracted structures or scar tissue which requires the surgeon to develop an individualized surgical plan for success. Soft tissue releases for exposure are substantial and result in significant alterations in balance, which may be especially true in revisions of kinematically aligned (KA) TKA cases that had not undergone prior soft tissue releases[9]. In addition to soft tissue considerations, component positioning can also significantly affect stability [10].

The technique described in this analysis employs an imageless navigation system, and technology assisting platforms such as these have demonstrated improvements in implant alignment and component positioning in the setting of RTKA. One large scale systematic review found that technology-assisted RTKA resulted in fewer outliers in hip-knee-ankle angle, superior component positioning, and better joint-line restoration compared to conventional techniques[11]. Additionally, retrospective reviews of imageless, robotic-assisted RTKA have reported favorable postoperative outcomes and improved preservation of posterior condylar offset[12,13]. Despite these proven advantages of navigation, accurate soft tissue balancing and consistent implant positioning remains a challenge in the setting of revision.

This proof-of-concept analysis will explore the accuracy of the proposed technique and outline the workflow to re-establish the joint-line and create a balanced revision knee replacement. We hypothesize that this novel technique and systematic workflow can consistently produce accurate gap balance in a controlled cadaveric setting and may serve to decrease the rates of failure due to instability when adopted clinically.

Materials and Methods

Approval by the Institutional Review Board (IRB) was not required as this study involved cadaveric subjects and no living participants.

PREOPERATIVE CONSIDERATIONS:

The only absolute contraindication to this technique is the absence of collateral ligament stability or severe uncontained bone loss greater than available augmentation. Pre-operative x-rays must be assessed for areas of bone loss, heterotopic bone formation, and extensor mechanism injury or contracture. The distance from the top of the fibular head to the desired joint line must be noted pre-operatively and is given the designation ***d*(JL)** (**Figure 1**).

Implant templating is not required for this procedure, however, the surgeon must be aware of the true thickness of the proposed revision tibial baseplate including the thinnest polyethylene insert (**Figure 2**) along with the thickness of the femoral condyles in the distal and posterior condylar aspects, (designated ***distance*** **(Distal Femur Implant)** or ***d*(DFI)** and ***distance*** **(Posterior Femur Implant)** or ***d*(PFI)**, respectively) (**Figure 3A** and **Figure 3B**).

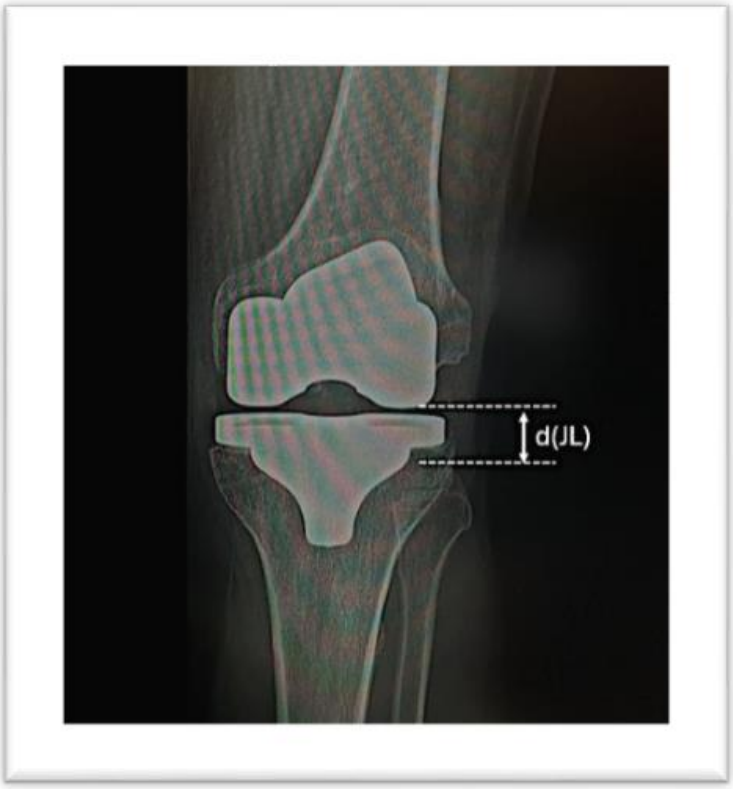

FIGURE 1. Shown in the image above is the distance from the top of the fibular head to the desired joint line, designated distance(Joint Line) or d(JL).

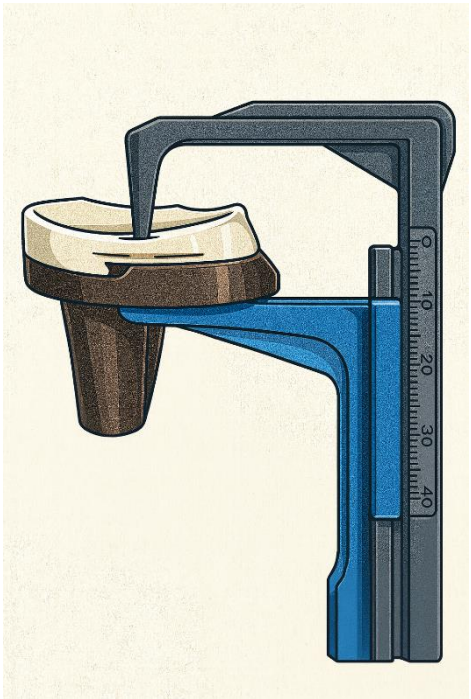

FIGURE 2. Shown in the image above is the measurement of the true thickness of the tibial baseplate and thinnest polyethylene insert.

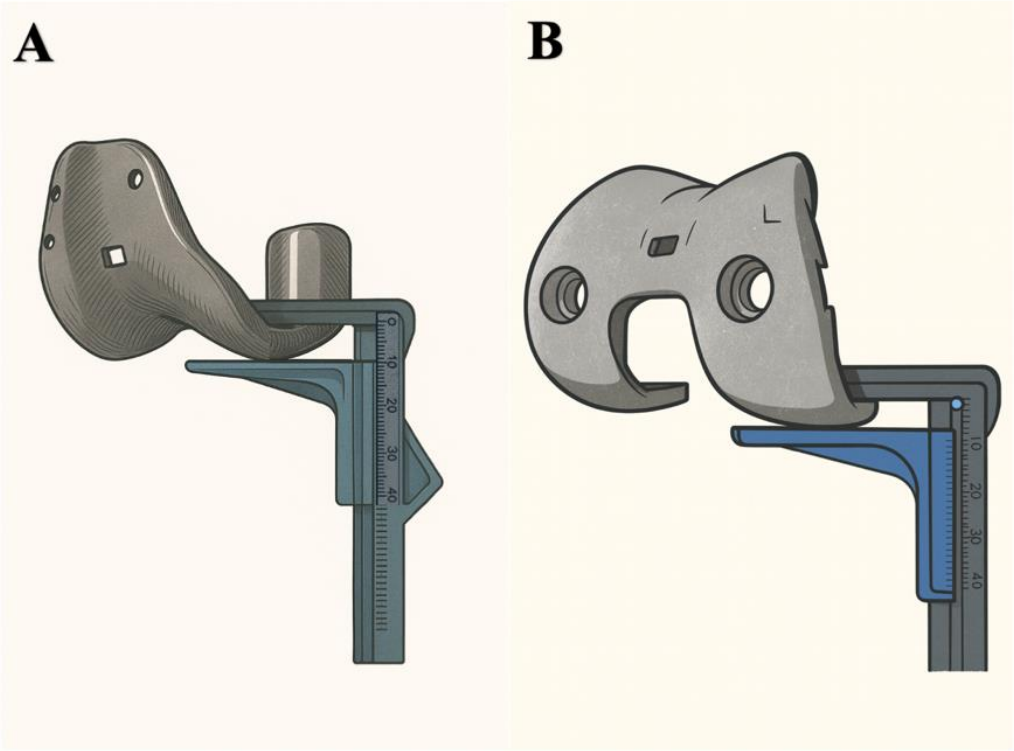

FIGURE 3A and 3B. Displayed above is the measurement of the thickness of the distal and posterior aspects of the femoral condyles, designated distance (Distal Femur Implant) or d(DFI) (A) and distance (Posterior Femur Implant) or d(PFI) (B), respectively.

OPERATIVE TECHNIQUE:

Implant and cement removal is performed at the treating surgeons' discretion. In cases of revisions involving cruciate retaining knees, the PCL is resected prior to tibial component removal. Complete debridement of the posterior capsule is performed in all cases of infection. In aseptic cases, patellar components are inspected for wear and position with revision performed on a case-by-case basis.

Intramedullary alignment of the tibia may be performed. The author utilizes extramedullary navigation equipment (Orthalign, Irvine, California, USA) for the tibial resection mounted in the same fashion as a primary knee replacement, the spiked ACL gauge is positioned directly over the intramedullary canal. The tibial cut is set to 0 degrees varus and 0 degrees of posterior slope to account for revision implants. In the absence of severe bone loss requiring tibial hemi-augmentation, depth of cut is set to 2mm from lowest cortical point (**Figure 4**).

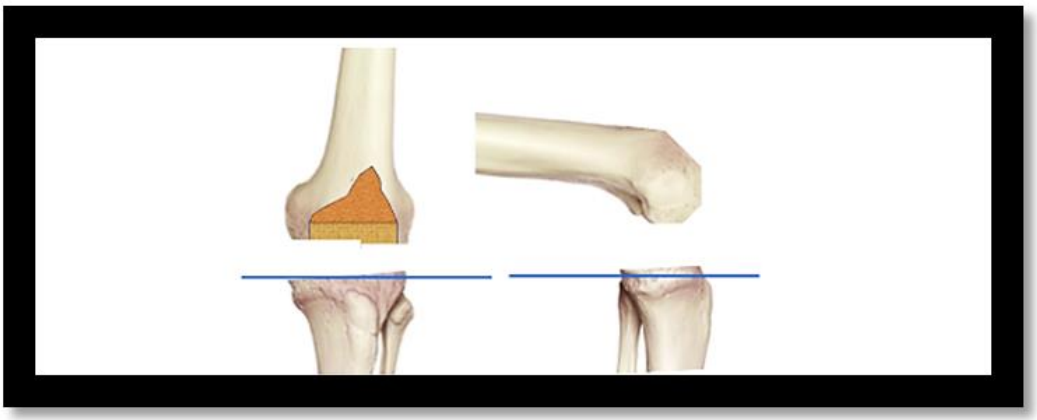

FIGURE 4. Shown above is the tibial resection after implant removal with depth of cut set to 2mm from the lowest cortical point.

If tibial hemi-augmentation is required, this can be performed in standard fashion with revision intramedullary guides. If using navigation, the hemi-augmentation cut is prepared utilizing the stylus set for resection referencing the freshly cut opposite surface.

At this stage the tibia represents the stable foundation that the remainder of the knee is to be built upon. The tibial keel can be prepared per implant manufacturer design along with a cone as needed. The top of the fibular head is located with palpation and a spinal needle. The distance from the superior most tibial surface to the tip of the fibular head is given the designation ***distance*** **(Tibia cut – Fibular head)** or ***d*****(TF)** (**Figure 5**).

The sum of the distance from the superior most tibial surface to the top of the fibular head **d(TF)** and the distance from the top of the fibular head to the desired joint line **d(JL)** gives the ideal total tibial thickness, designated **i(TTT)** (**Figure 6**).

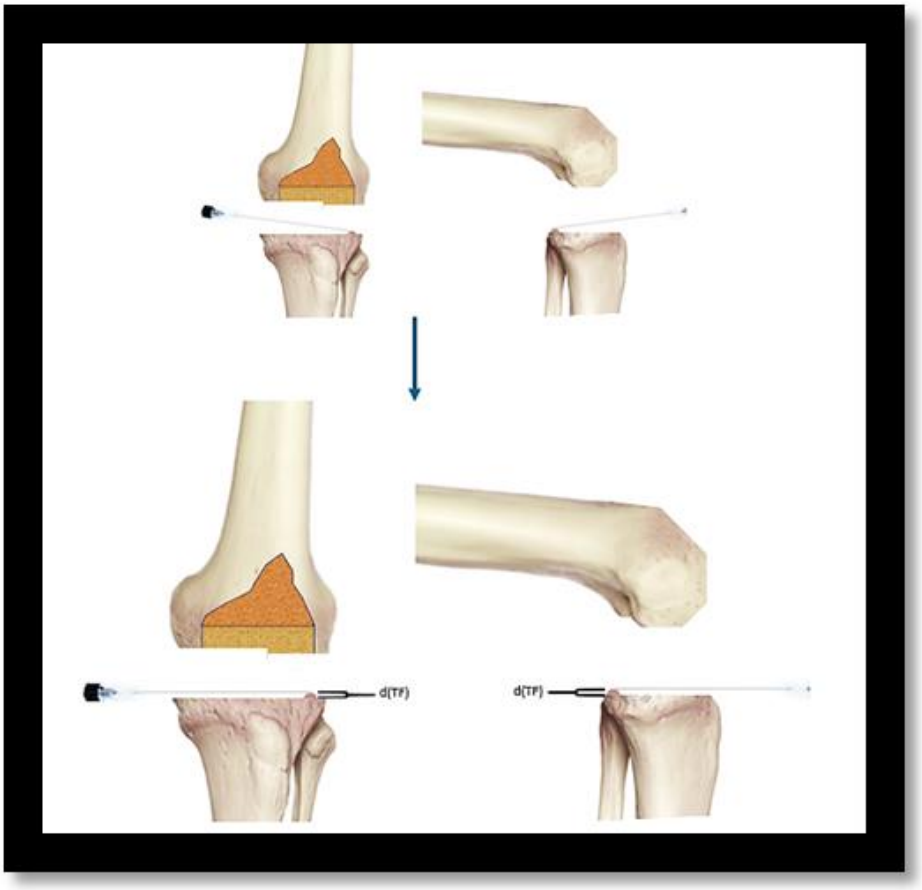

FIGURE 5. Shown in the image above is the distance from the superior most tibial surface to the tip of the fibular head, designated distance(Tibia cut - Fibular head) or d(TF). The spinal needle is used to locate the tip of the fibular head, and then it is held parallel to the tibial surface.

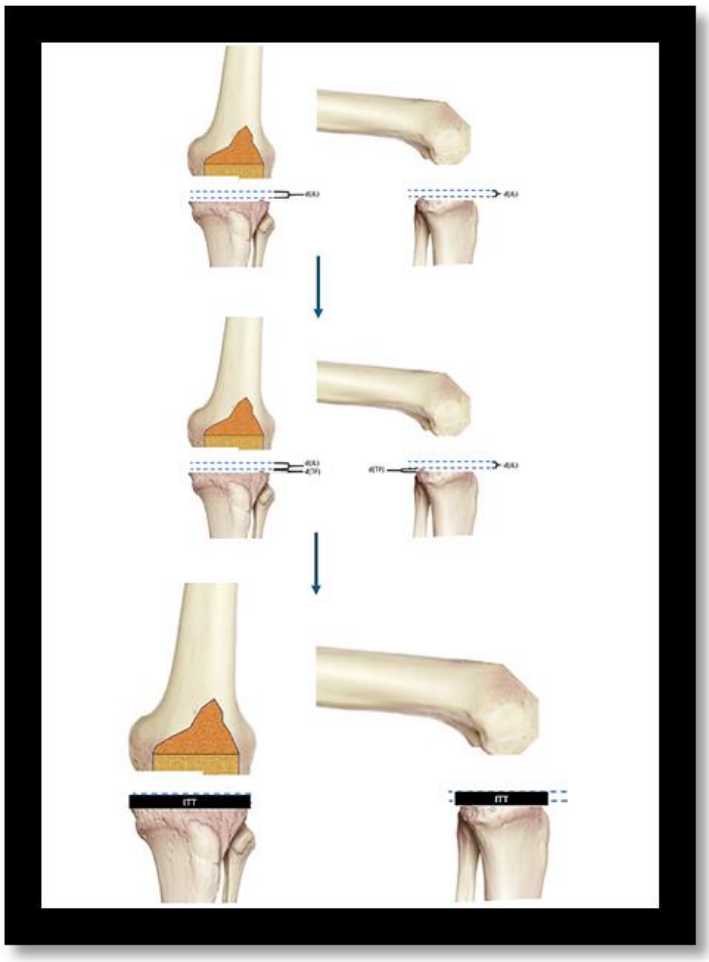

FIGURE 6. Shown above is the measurement of the ideal total tibial thickness, designated i(TTT).

d **(TF) + *d*(JL) = ideal Total tibial thickness i(TTT)**

The total tibial thickness should be viewed as a desired range of ±2-3mm. It will be comprised of the tibial baseplate, the polyethylene insert, and any pan-tibial augmentation. Note that the total tibial thickness intentionally does not include hemi-augmentation. Balancing the femoral component may be easier with slight adjustments in the total tibial thickness.

The femur must now be addressed. Before proceeding, the medial and lateral, flexion and extension gaps are measured. If the tibia was prepared for hemi-augmentation a spacer is placed in the defect under the tibial balancing paddle to create a single flush surface for this measurement. Gap balance assessment provides four values (**Figure 7**):

It should be noted that in cases of RTKA, resection of the posterior capsule and absence of posterior condyles can lead to extension pseudolaxity, and as such a correction, designated ***d*****(cor),** is performed removing 1mm from the **(MEG)** and **(LEG)** **(Figure 8)**.

Balancing the knee can now be performed with the basic principles as follows:

- Joint line within 3mm of **i(TTT) with** up to 5mm supported in literature[14].
- Desired medial joint space, designated ***d*****(MJS)** (senior author utilizes 2mm in flexion and extension).
- Desired lateral joint space, designated ***d*****(LJS)** (senior author utilizes 2mm in extension and 3 mm in flexion).

The next step is to reduce flexion and extension gaps by the known femoral implant thicknesses, reduce the extension gaps by the correction factor, and incorporate the desired joint space into the preserved space **(Figure 9)**.

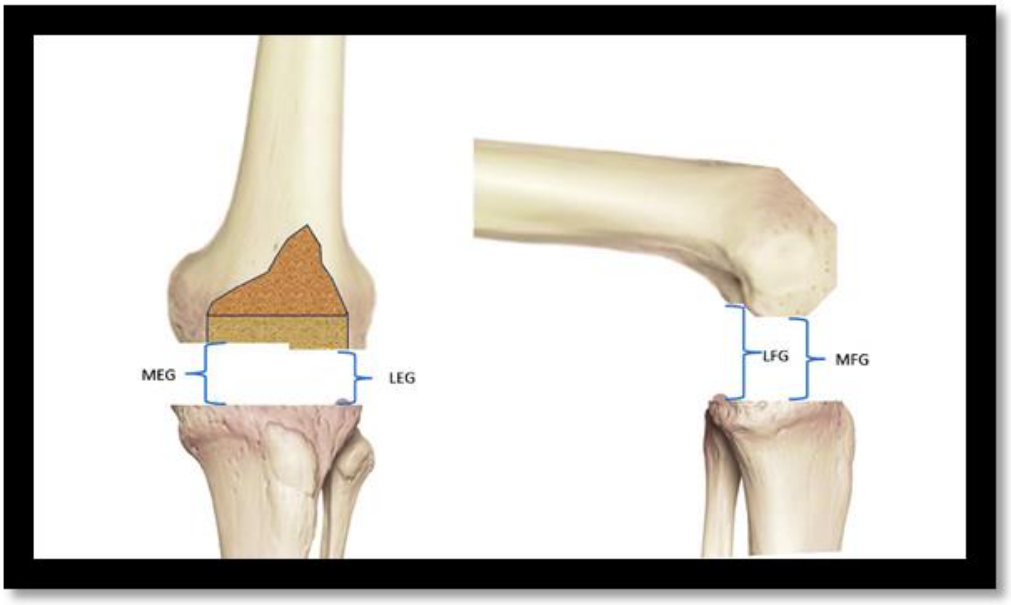

FIGURE 7. Shown above is the designation of the medial extension gap (MEG), lateral extension gap (LEG), medial flexion gap (MFG), and lateral flexion gap (LFG).

Medial Extension Gap (MEG)
Lateral Extension Gap (LEG)
Medial Flexion Gap (MFG)
Lateral Flexion Gap (LFG)

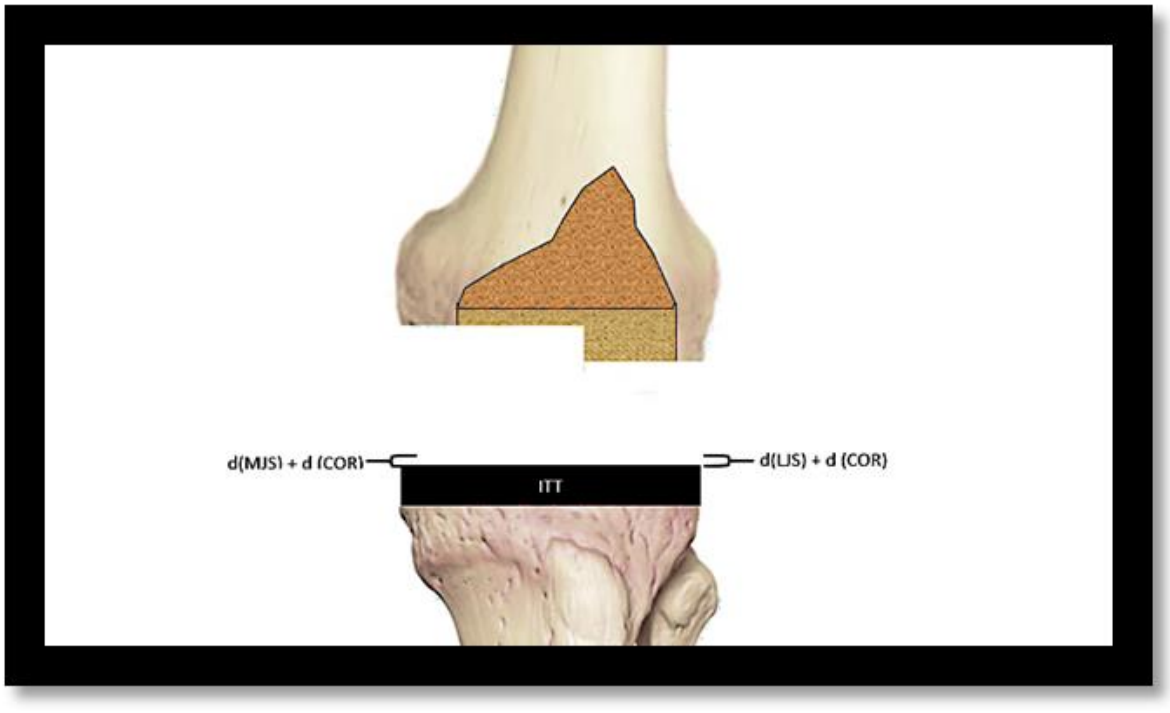

FIGURE 8. Displayed in the image above is the desired medial joint space, designated d(MJS) of 2mm, desired lateral joint space, designated d(LJS) of 2mm, and correction for extension pseudolaxity, designated d(cor).

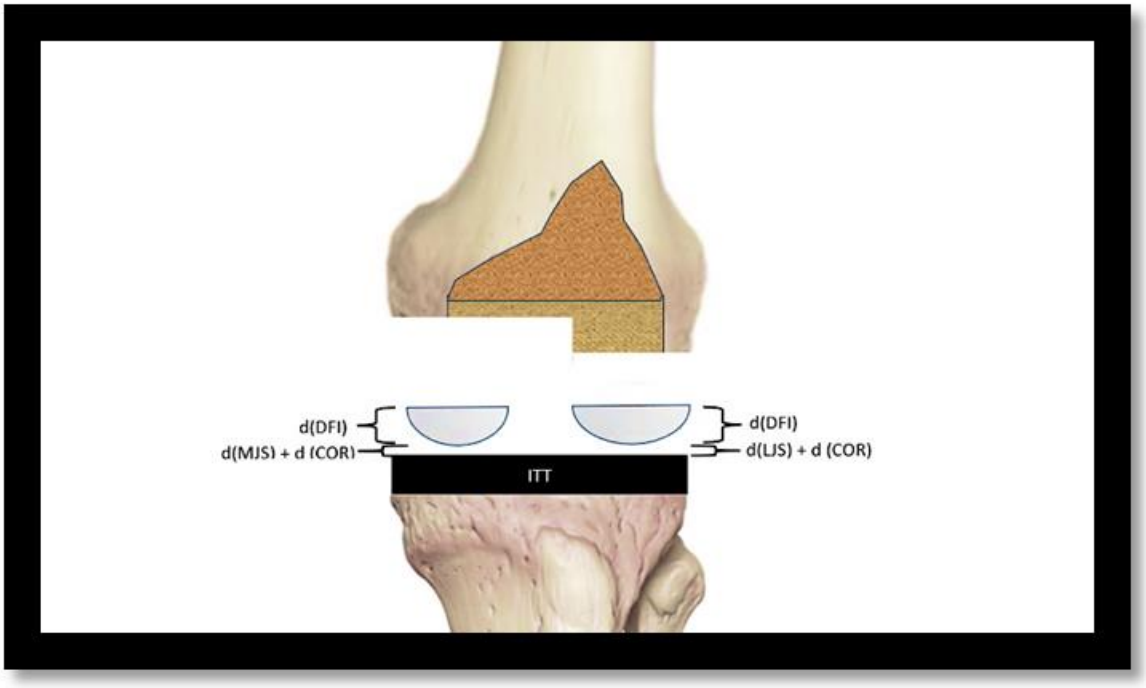

FIGURE 9. Shown in the image above is the medial extension gap and lateral extension gap after reducing the gap by the known distal femur implant thickness, designated d(DFI) or the posterior femur implant thickness, designated d(PFI) and accounting for the desired joint space and correction factor. This measurement is designated (MEG)1, (LEG)1, (MFG)1, or (LFG)1.

$(MEG) - d(DFI) - d(MJS) - d(cor) = (MEG)_1$
$(LEG) - d(DFI) - d(LJS) - d(cor) = (LEG)_1$
$(MFG) - d(PFI) - d(MJS) = (MFG)_1$
$(LFG) - d(PFI) - d(LJS) = (LFG)_1$

Next, all measurements are then reduced symmetrically by the surgeon selected total tibial thickness, designated **s(TTT) (Figure 10)**. If this results in a negative number on some of the measurements this is acceptable as it allows for resection of bone without the need for augmentation.

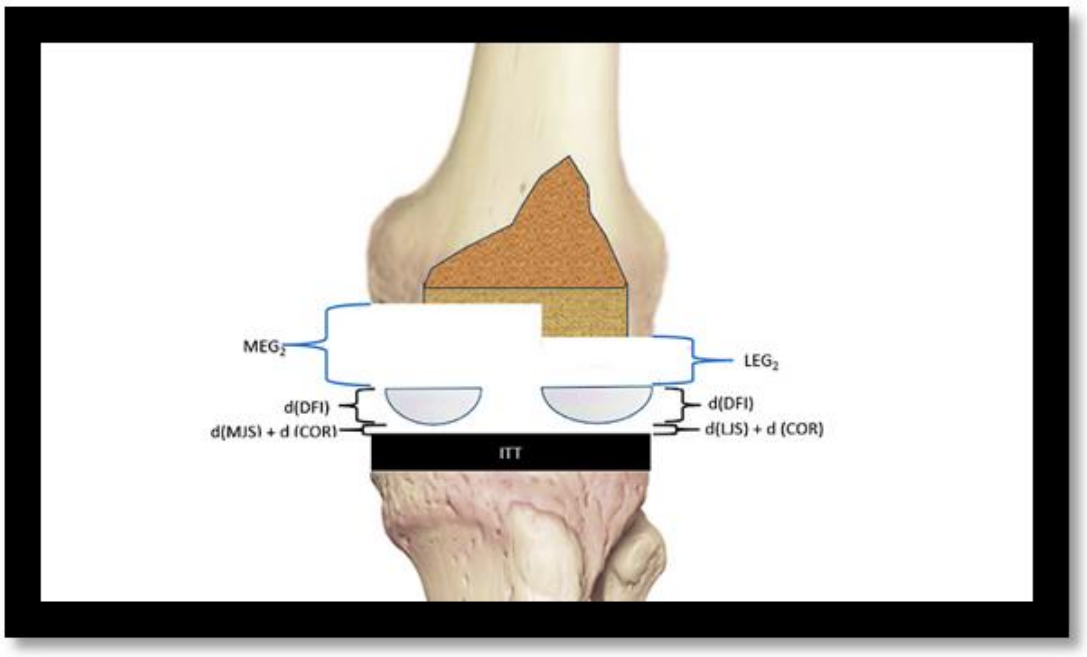

FIGURE 10. Displayed in the image above is the medial extension gap and lateral extension gap after accounting for the surgeon selected total tibial thickness, designated s(TTT). This measurement is designated (MEG)2, (LEG)2, (MFG)2, or (LFG)2.

$(MEG)_1 - s(TTT) = (MEG)_2$
$(LEG)_1 - s(TTT) = (LEG)_2$
$(MFG)_1 - s(TTT) = (MFG)_2$
$(LFG)_1 - s(TTT) = (LFG)_2$

At this stage of the technique, each gap measurement now indicates the required respective resection +/- augmentation needed to obtain a well-balanced knee. Measurements are dependent on implant manufacturers' available femoral augment sizes. This study used an implant system with 5mm augments that can be stacked to a maximum of 10mm. If a measurement is negative, then it becomes the resection setting and no augment will be needed. If it is between 1-5mm, subtract 5mm and that becomes the amount of bone needed for resection to perfectly accommodate a 5mm augment. If the measurement is between 6 – 10mm then subtract 10mm and that becomes the amount of bone resection needed to perfectly accommodate a 10mm augment in that space. Measurements greater than 10mm would suggest bone loss is greater than the implant system could manage, this may be salvaged by raising the joint line using a thicker tibia insert but would be left to the discretion of the treating surgeon.

The next step is to prepare the femur for the implant, and this can be performed with intramedullary referencing. The guide rod is placed, and the distal femoral cut block is pinned in place utilizing an adjustable tibial stylus to set the depth of the distal femoral cut. To preserve medial collateral ligament isometry, priority is given to the medial condylar resection. The medial femoral condyle resection depth is set to the value calculated to be $(MEG)_2$, using the minus 5 or 10mm slot as needed. The depth of cut on the lateral side can be set similarly. Alternatively, the lateral resection depth may also be determined by using the femoral cutting block and resecting the condyle through the cut slot that will provide at least 50% bone contact with the implant. This can be compared to the predicted $(LEG)_2$ value to establish a predicted laxity in the lateral extension compartment. Laxity greater than 4mm may require additional balancing or constraint.

Next, posterior condyles must be resected in a similar manner. The 4-in-1 cut block is applied to the femur with the appropriate distal augments selected, and the adjustable tibial stylus is utilized medially on the most posterior point of the condyle set to $(MFG)_2$, utilizing the 0, 5 or 10mm cutting slot as appropriate. Resection of the lateral side can be set according to the $(LFG)_2$, again utilizing the 0, 5 or 10mm cutting slot as appropriate. Using the transepicondylar axis (TEA) as a reference, the surgeon must determine if the lateral resection would place the cutting guide in excessive internal rotation. If necessary, the TEA can be used for positioning, maintaining the medial posterior condylar resection depth and a higher level of constraint or additional balancing may be required. The posterior resection and posterior chamfer cuts may be performed. The anterior chamfer cut and anterior flange are then considered at this stage; the cutting block may need to be exchanged to avoid anterior notching. Removal of a previous implant often negates this step unless a significant rotational discrepancy is present. Using an angel wing and saw blade in the appropriate posterior augment slots allows perfect alignment of a new 4-in-1 cutting block. The femoral box is then prepared per the selected implant manufacturers' equipment. Trial implants are placed to confirm balance, patellar tracking, and range of motion with the lowest level of constraint used for trialing. The author utilizes constructs with short, cemented stems. Implants are placed in a standard fashion.

CADAVERIC ANALYSIS:

This workflow was performed on eight cadaveric lower extremities. The inclusion criteria applied to cadaveric specimens were adult specimens with intact bilateral lower extremities. Exclusion criteria included specimens with absent lower extremity anatomy, prior knee surgery, traumatic distortion, and inadequate preservation. All cadaveric specimens were in the sixth to eighth decade of life without any prior surgeries or injuries that would distort the natural anatomy of the knee. Body habitus and lower extremity alignment did not exclude specimens. No specimens were excluded from this study.

The process began by performing primary, caliper-verified kinematically aligned TKA using an imageless-accelerometer based navigation platform[15]. Pre-operative data and bony resections recorded in the initial operation are recorded in **Table 1**. Each lower extremity then underwent conversion to mechanically aligned RTKA[9]. The cadaveric specimens did not have definitive implantation of previous components and therefore implant and cement removal were not performed as part of the cadaveric technique. To replicate the bone loss typically seen in RTKA, all lower extremities were artificially damaged using a saw blade and mallet. Balance after conversion to the mechanical axis and after subsequent artificial bony defects are recorded in **Table 2**. Gap measurements and data relevant to the technique described in this study are shown in **Table 3**.

STATISTICAL ANALYSIS:

SPSS version 29.0.2.0(20) (IBM Corp, Armonk, USA) was used to carry out necessary statistical analysis for the cadaveric data. Frequencies for mean and standard deviation (SD) were obtained for continuous data and recorded in **Table 2** and **Table 3**. Mean and SD are shown as mean±SD. An artificial Intelligence (AI) tool, ChatGPT-5 (OpenAI, San Francisco, CA) was used to develop **Figure 2**, **3A**, and **3B**. A narrated video clip demonstrating the described technique is provided with this study (**Video 1**).

Results

Eight specimens underwent primary, caliper-verified kinematically aligned TKA using an imageless accelerometer-based navigation platform. Pre-operative radiographic data, planned resections, and caliper measurements of bony fragments were recorded (**Table 1**).

TABLE 1. Pre-operative radiographic data and measurement of bone fragments in the primary operation. Mechanical lateral distal femoral angle (mLDFA) and mechanical medial proximal tibial angle (mMPTA).

Specimen Number and Laterality	1 left	1 right	2 left	2 right	3 left	3 right	4 left	4 right
	Caliper Measurements (mm)							
mLDFA (deg)	88.0	88.0	86.5	86.5	84.0	84.0	89.0	88.0
mMPTA (deg)	86.0	86.0	86.0	86.0	86.0	86.0	86.0	85.0
Femoral valgus (deg)	2.00	2.00	3.50	3.00	6.00	6.00	1.00	2.00
Femoral flexion (deg)	3.00	3.00	3.50	3.00	4.00	4.00	4.00	4.00
Medial distal femoral fragment (mm)	8.00	9.50	8.00	9.00	6.00	7.00	8.00	7.00
Lateral distal femoral fragment (mm)	8.00	9.50	8.00	9.00	7.00	7.00	8.00	7.00
Medial posterior femoral fragment (mm)	8.00	8.50	9.00	8.00	7.00	8.00	7.00	8.00
Lateral posterior femoral fragment (mm)	8.00	8.00	9.00	8.00	8.00	8.00	7.00	8.00
Tibial varus (deg)	4.00	4.00	3.50	4.00	4.00	4.00	4.00	5.00
Tibial slope (deg)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Medial tibial fragment (mm)	10.0	9.00	8.00	8.00	8.00	10.0	7.00	7.00
Lateral tibial fragment (mm)	10.0	9.50	9.00	10.0	8.00	10.0	9.00	9.00

Gap measurements after conversion to mechanically aligned RTKA were recorded along with measurements after artificial creation of bony defects (**Table 2**). All proposed joint spaces were set at 1mm for the purpose of the study.

TABLE 2. Gap measurements after conversion to mechanically aligned revision total knee arthroplasty and after artificial creation of bony defects.

Gap measurements after converting to mechanical aligned revision	**Mean±SD**
Medial extension gap (mm)	23.6±1.92
Lateral extension gap (mm)	27.6±2.56
Medial flexion gap (mm)	26.4±2.20
Lateral flexion gap (mm)	29.9±4.19
Gap measurements after artificial creation of bony defects	**Mean±SD**
Medial extension gap (mm)	25.3±2.55
Lateral extension gap (mm)	28.3±2.55
Medial flexion gap (mm)	26.8±4.06
Lateral flexion gap (mm)	30.4±3.70
Distance from tibia to fibular head (mm)	1.88±2.17
Desired joint line height from fibular head (mm)	12.3±2.87
Selected total tibial thickness (mm)	14.5±1.41

Gap measurements and values relevant to the gap balanced RTKA technique described in this study were recorded (**Table 3**). All final gaps were all within 1mm (medial extension 0.38mm, lateral extension 0.63mm, medial flexion 0.75mm, and lateral flexion 0.25mm).

TABLE 3. Required bony resection and gap measurements during conversion to gap balanced revision total knee arthroplasty.

Required bony resections	**Mean±SD**
Medial extension gap (mm)	1.50±2.33
Lateral extension gap (mm)	1.50±0.93
Medial flexion gap (mm)	2.00±1.07
Lateral flexion gap (mm)	2.63±1.77
Balance after clean up cuts without augments	**Mean±SD**
Medial extension gap (mm)	27.5±3.82
Lateral extension gap (mm)	29.5±2.45
Medial flexion gap (mm)	30.8±2.60
Lateral flexion gap (mm)	32.8±3.69
Balance after clean up cuts with augments	**Mean±SD**
Medial extension gap (mm)	24.9±0.64
Lateral extension gap (mm)	25.1±1.13
Medial flexion gap (mm)	24.3±2.05
Lateral flexion gap (mm)	23.8±1.83
Balance with augments - implant thickness	**Mean±SD**
Medial extension gap (mm)	0.38±1.06
Lateral extension gap (mm)	0.63±1.06
Medial flexion gap (mm)	0.75±1.16
Lateral flexion gap (mm)	0.25±1.04

Augments used for each specimen are recorded in **Table 4**. 10mm posterolateral augments were required in all specimens.

TABLE 4. Augments used in the cadaveric specimens.

Augments used	1 left	1 right	2 left	2 right	3 left	3 right	4 left	4 right
Medial extension gap (mm)	5	5	0	0	0	5	10	0
Lateral extension gap (mm)	5	5	5	5	5	5	5	5
Medial flexion gap (mm)	5	5	5	5	10	5	10	5
Lateral flexion gap (mm)	10	10	10	10	10	10	10	10

Discussion

The results of this analysis using the described technique show consistent gap balance in a series of cadaveric specimens. Similar to the process used in this technique, though with different landmarks, Gungor and Ök used a spacer block tool (SBT), referencing anatomical landmarks such as the fibular head, adductor tubercle, and medial epicondyle to restore the joint line[16]. Lacono et al. found that the ratio of the adductor tubercle to joint-line distance and trans-epicondylar femoral width could determine the physiological joint line in RTKA[17]. Hofman et al., claimed that the joint line should be within 4mm of the patients native knee, Elbardesy et al., also set 4mm as the upper limit, and Buller et al., supports maintaining the joint line within 5mm of the preoperative height[14,18,19]. In this study the joint line was maintained within 3mm of the i(TTT).

The tensioning paddles of the gap balancing device used in this study applied a force of 250-300N (Orthalign, data on file) while Becker et al., identified an acceptable distracting force of 150 N in extension and 140 N in flexion[20]. Given that the distracting force applied to the supporting ligaments in this study was higher than ideal, it is perhaps most appropriate to aim for 2mm as the desired joint space using this technique with the digital gap balancing platform. Interestingly, 10mm posterolateral augments were required in all cases, all knees were converted from kinematic alignment to mechanical alignment which may account for the increased posterolateral augmentation in all specimens[9,15].

Robotic platforms have gained traction in recent years in the setting of revision with one such system (CORI Surgical System, Smith and Nephew, Memphis, Tennessee, USA) showing favorable 90 day outcomes[12]. Kostretzis et al., presented a viable technique for RTKA without the use of advanced navigation using a restricted kinematic alignment protocol which showed promising mid-term results[21]. Perhaps some of the most meaningful data relating to the viability of assisting technology in revision knee replacements is found in two systematic reviews. Innocenti et al. and Olaonipekun et al. both identified superior radiographic accuracy, particularly coronal plane alignment and joint line restoration, compared to conventional techniques[11,22]. This was especially true with extreme alignment deformities. However, despite enhanced radiographic accuracy and planning, the advantages of navigation did not translate into superior clinical outcomes.

The imageless navigation system used in this technique has been proven to be a useful tool to allow for precision and objective gap balance feedback in the setting of RTKA[22]. Wells and Purcell begin with distal femoral resections though the technique in this study begins with a proximal tibial resection which allows for more intraoperative personalization by adjusting femoral component positioning to achieve appropriate balance in medial and lateral compartments in flexion and extension independently. This technique differs from others in that a systematic implant agnostic algorithm is used to reconstruct the knee around a pre-defined joint line without

advanced imaging and permitting use in cases where registration may be challenging, such as arthrofibrosis or cases with absent articular surfaces. In addition, many of the studied navigation systems in the literature make intraoperative plans prior to complete soft tissue debridement which could impact implant positioning. The present technique provides instantaneous feedback which could perhaps allow for more accurate intraoperative decision making, implant sizing, and resulting implant positioning.

The technique described followed mechanical alignment principles for proof of concept, however this workflow may be applied to the inverse kinematic alignment (iKA) technique as well. iKA involves restoring the native tibial anatomy through bone cuts that correspond to the implant thickness and balancing the joint through adjusting the orientation of the femoral cuts[23]. The tibia first approach in iKA, compared to femur first in standard KA may allow for more flexibility in balancing the joint, particularly in the setting of revision where tibial bone stock is often limited. Winnock de Grave et al., in a series of patients undergoing robotic assisted iKA or MA (mechanical alignment) TKA, found comparable clinical outcomes at the 12 month follow-up though the patients with a preoperative varus deformity who underwent iKA reported significantly better satisfactory scores than MA[24].

This analytical technique guide is not without limitations. The cadaveric analysis of this technique included eight lower extremities which could introduce the potential for a type-II error. Additionally, inherent cadaveric factors and reliance upon adequate preservation could underscore the true, in vivo gap measurements using this technique. However, clinically this has technique has been utilized by the author in multiple different presentations with consistent results. While this study utilized navigation for the tibial resection, this technique can be implemented in the setting of intramedullary referencing equipment with any device capable of measuring medial and lateral, flexion and extension gaps independently. The bone loss following artificial creation of bony defects may underestimate the true amount of bone destruction seen in RTKA, though augment utilization was consistent with what is typically seen in RTKA. All cadaveric specimens had Anderson Orthopaedic Research Institute (AORI) Classification Type 1 defects without significant metaphyseal damage [25].

Conclusion

This analysis presents a novel technique and proves the technical feasibility of the gap-balanced RTKA workflow under experimental conditions. Though the senior author has employed this technique in the clinical setting, further analysis with long-term follow-up of patient satisfaction scores and complications is warranted. In the future, with further clinical testing, we hope this surgical technique may provide a viable, reproducible approach to RTKA and contribute to improved patient satisfaction through reduction in post-operative instability.

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Conflicts of Interest and Sources of Funding:

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