The "linked soft tissue guided technique": a novel method for cutting the tibia while performing a kinematic femoral alignment in total knee arthroplasty

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Abstract: Kinematic total knee arthroplasty (TKA) has gained much attention in recent years. While most surgeons agree on how to adjust the femoral component, cutting the tibia and restoring it to its pre-arthritic state while maintaining the native laxity of the soft tissue envelope remains an unsolved issue. In this study we present a novel, easy and reproducible technique for cutting the tibia when performing a kinematic TKA. A novel technique for kinematic TKA ("linked soft tissue guided technique") was developed for planning and executing the tibia cut, without the use of patient specific instrumentations nor navigation. Patient reported outcomes 6 months post op suggested a learning curve of approximately 20 patients. In 26 patients who had undergone a previous mechanical knee arthroplasty, a comparison was made between the two knees in regards to pain and function. Our preliminary results show an advantage for the novel technique regarding patient satisfaction. In conclusion, the "linked soft tissue guided technique" is a simple, comfortable, and a reproducible technique, and may aid surgeons in their transition to kinematic alignment arthroplasties.

Keywords: Knee; replacement; arthroplasty; kinematic; alignment

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Introduction

One of the fundamental aspects of performing a standard total knee arthroplasty (TKA) is cutting the femur and tibia perpendicular to their mechanical axis. However, a better understanding of native knee kinematics, constitutional limb alignment, ligament isometry, single radius morphology of the femoral condyles, cylindrical axis of motion and joint line dynamic obliquity (1), altogether have opened the door for rethinking and rescaling our traditional habits.

In search for a more native alignment, the concept of kinematic alignment (KA) has been proposed. While still debatable, several studies have shown a clinical advantage to this technique over mechanically aligned total knee replacement (MA) (1,2). The main concept of the kinematic approach is restoration of the pre arthritic joint lines throughout the knee movement (3-5) and while most surgeons use the same philosophy for performing the femoral cuts, the tibial cut continues to be a matter of different approaches (3,6,7). Inappropriate tibial cutting may affect joint line obliquity (8), cause femoral component malrotation (9,10), instability (11), affect knee adduction moment, and consequently lead to higher failure rates and dissatisfaction.

In recent years kinematic TKA gained much experience. This experience has led us to develop a simple, novel surgical technique for cutting the tibia which is both loyal to the concept of kinematic alignment and easy to reproduce. In this study we present a step by step guide to perform a kinematic aligned knee using the "linked technique" and we present our clinical experience using this technique.

Patient selection and workup

All consecutive primary TKA at a single center between August 1st 2017 and March 2018 were included in this study.

Exclusion Criteria was limited to revision surgeries.

All surgeries were performed by a single surgeon (Y Bar-Ziv) with over 20 years of surgical experience in joint arthroplasty. Overall, 146 patients had undergone a kinematic TKA during that time, of which 26 had a previous mechanically aligned TKA performed on their contralateral knee.

Surgical technique

The principals of the described technique combine known methods for knee replacement techniques (kinematical alignment/measured resection/gap balancing) into one, complete, harmonic and reproducible technique. This is accomplished by a simple sequence of three key surgical steps: (I) kinematically aligning the femoral component; (II) creating a limb alignment by Gap balancing in extension; (III) linking the tibial cut to the kinematically aligned femur. *Table 1* summarizes the key points of the technique. *Figure 2* shows the surgical instruments used. Caliper assurance up to a 0.5 mm was accepted and neglectable varus/valgus laxity in extension was mandatory to achieve. Medially stabilized implant (Sphere, Medacta International) was utilized in all cases.

Pre-operative preparation and post-operative management are standard as custom for knee arthroplasty.

Femoral component

A small mid line skin incision is made, followed by a mini medial para patellar arthrotomy. The patella is subluxed to the lateral gutter, and a meticulous osteophytectomy is performed to allow for better exposure. The anterior femoral cortex is exposed with a periostal or a cub elevator. The distal femur is then inspected to identify the erosion pattern. If there is still cartilage remanence—it is recommended to remove it with a curette until reaching the subchondral bone. The correct offset reference block is chosen based on the erosion pattern (worn-worn, unworn-unworn, worn-unworn) (*Figure 3A,B*). The anterior cortex referencing device is then connected to the distal cutting reference block (*Figure 3C,D*). It is crucial to position the construct flush on the anterior cortex and at the same time flush to the distal femur to avoid malpositioning in the sagittal plane. After verifying correct positioning of the device, it is secured using two 3.2 mm threaded pins to the bone. Distal femoral cut is performed with a saw in a regular manner. The medial and lateral distal bone cuts are then measured using a caliper as described previously (3). The knee is then hyperflexed and the wear pattern of the posterior condyles is assessed as well. A posterior reference device is then used, set to 0 degrees of rotation relative to the posterior condylar axis. Loss of cartilage is compensated as previously described with dedicated shims in 1 mm increments (12,13). Sizing of the femoral component is then measured. A 4:1 block is placed inside the drilled holes and secured with additional 2 short headed threaded pins. Anterior cortex notching is evaluated with an angle wing. Upsizing or downsizing of the 4:1 block is possible in order to achieve the best fit. Posterior cut is then performed, followed by caliper based reassurance.

Tibial component

After the femoral cuts are performed, menisci and posterior osteophytes are carefully removed using a curved osteotome. Natural tibial rotation is marked by placing a tibial trial base plate just above the plateau in its best fit and by drilling two parallel holes through the pin holes (which will guide the rotation following the tibial osteotomy). Recreation of natural limb alignment is then achieved by gap balancing in extension; the femoral trial is impacted and the leg is extended. Special shims (1–6 mm) are then used as feeler gauge to gap balance the knee in extension; they are placed gradually between the femoral trial and the native (eroded) tibia until full balance is achieved (no opening at Varus or valgus and rotations stress at full extension). This balancing technique will re-align the limb (distract the tibia) and restore natural tension and stability in full extension without any need to release or manipulate any soft tissue structures. The balanced knee is then flexed to 90 degrees and stability is assessed throughout the range of flexion. The ability to assess the stability throughout full range of motion is an important part of the presented technique. This evaluation is possible using the femoral *in situ* trial approach. In this approach we examine the knee throughout the range of motion after the trial femoral component has been placed. This restores the femur to its pre arthritic position. This in turn creates a situation where the trial femur is articulating against native tibia, that may be eroded and sometimes may even present with bone loss. For that reason the tibia should be compensated later on by 1–5 mm shims as referenced (guided) by the soft tissue envelope (*Table 1*).

Table 1 Summary of the surgical technique, including pearls and pitfalls to it

Stage	Surgical notes	Pearls and pitfalls
Knee exposure (*Figure 1A*)	Skin incision and arthrotomy	May be performed by any approach.
	Partial fat pad excision and lateral patellar subluxation	We do not recommend everting the patella as this may compromise the lateral retinacular structures that we aim to save
	Meticulous osteophytectomy	–
	ACL and PCL are sacrificed	–
	Anterior femoral cortex exposed	3 cm proximally to the trochlea is usually enough and an excessive synovectomy is not required
Femoral preparation	Identification of the erosion pattern	If there are still cartilage remanence it is recommended to remove them to allow direct contact with the bone structure
	The correct reference block (2 mm) is chosen based on erosion pattern	The thickness of the prosthesis is 9 mm distally
	The Anterior cortex referencing device is connected to the distal cutting assembly (*Figure 1B*)	
	Distal femoral cut	Reassurance of the correct osteotomy using the caliper technique should be done. For Varus knees, we expect an average medial distal cut of 6 mm (+2 mm cartilage wear + 1 mm saw kerf = 9 mm = implant thickness *Figure 1C*) and for the distal lateral – 8 mm (usually no cartilage wear + 1 mm saw kerf = 9 mm – implant thickness)
	The posterior femoral erosion pattern is assessed in hyper-flexion and the femoral sizer is set to 0 degrees of rotation relative to the posterior condyles (*Figure 1D*)	Fixation to the distal femoral surface is done with 2 short headed threaded pins
	A 4:1 block is placed inside the drilled holes and secured with additional 2 short headed threaded pins	We do not raise or lower the 4:1 block from its original placement as this may compromise the natural kinematic alignment of the femoral component
	Posterior cut is done first followed by caliper based reassurance	We generally expect for both posterior medial and lateral cuts to be 7 mm
Soft tissue guided balancing	Menisci are removed and posterior osteophytes are carefully resected using a curved osteotome	In the presence of flexion contracture a posterior capsular release is performed
	Femoral trial (*Figure 1E*) is impacted and the leg is extended	–
	Extension gap is balanced using special shims (1–6 mm). Patellar tracking and tension in flexion is assessed with the shim in place (*Figure 1F*). Place the correct shim (usually 2–3 mm thick) between the femoral trial and the native (eroded) tibia to achieve full balance	Our goal in full extension—neglectable varus/valgus laxity—no opening with varus or valgus stress
		20–60 degrees of flexion—aim for minimal opening (1 mm) at the medial compartment for valgus stress and 2–3 mm opening at the lateral compartment to varus stress
		90 degrees of flexion—same as mid-flexion—minimal opening
		The 1 mm spoon enables fine tuning. If there is no laxity in flexion, it means that the spoon is too thick. If the laxity is increased, it means that the spoon should be thicker

Table 1 (*continued*)

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Stage	Surgical notes	Pearls and pitfalls
Linking the tibia to the femur	Knee is flexed to 90 degrees and femoral drill holes are put into place (*Figure 1F*)	Verify that the femoral drills are firmly attached
	Assemble the linkage instrument on the femoral peg drills proximally, and connect it to the tibial cutting guide (*Figure 1G*)	It should already be calibrated to the correct level of resection by the size of the femoral trial *in situ*—this will correspond to a 10 mm thick insert
	Verify that the knee is at 90 degrees of flexion and then secure the tibial cutting guide	Correct placement of this assembly will result in parallel tibial cut to the kinematic aligned femoral trial
	Partially subluxate the tibia anteriorly	May be performed with the femoral trial left in place
	Perform the tibial cut	
Trials and implantation	Trial (*Figure 1H*)	Examine soft tissue tension in extension and flexion and asses patellar tracking
	Preparation of the tibial base plate and femoral trochlea (*Figure 1I*)	–
	Extensive washout with jet lavage	–
	Cementation and placement of final components (*Figure 1J*)	–

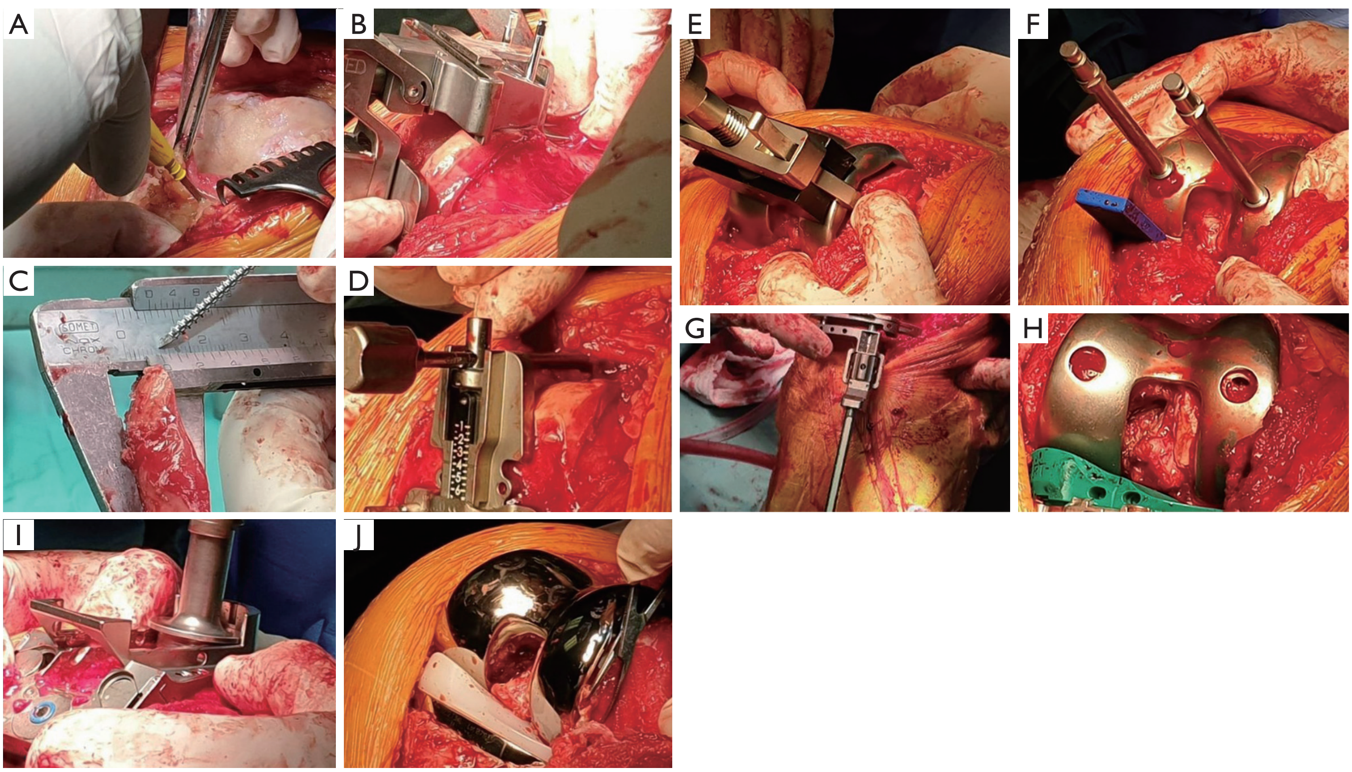

Figure 1 Stages of the "Linked Technique" TKA: knee exposure. (A) Anterior cortex referencing device is connected to the distal cutting assembly; (B) assessment of the distal cut thickness; (C) assessment of the posterior femoral erosion pattern; (D) femoral trial; (E) flexion and extension gap assessment with the shim in place; (F) attachment of the linkage instrument; (G) insertion of trial and assessment of the tension in flexion and extension; (H) preparation of the tibial base plate and femoral trochlea; (I) cementation and placement of final components (J).

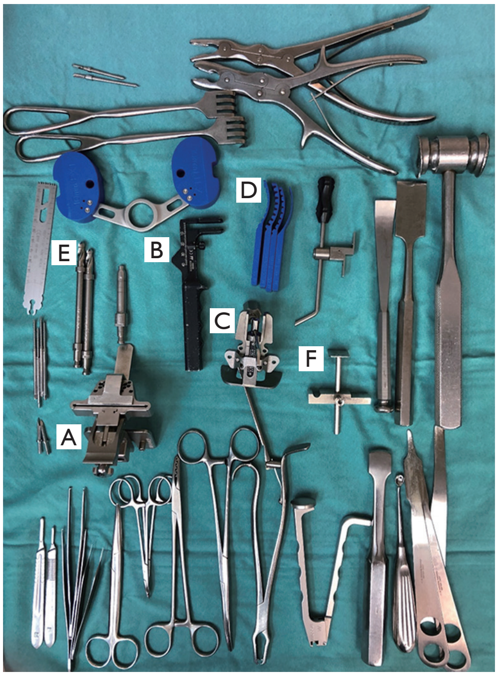

Figure 2 Surgical tray showing the (A) anterior cortex referencing device connected to the distal cutting reference block, (B) caliper, (C) sizer, (D) shims (1–6 mm), (E) peg holes drills, (F) linkage device.

Next, two peg holes are then drilled in the distal femoral trial and the linkage instrument is placed on them (*Figure 4*). After verifying that the knee is flexed to 90 degrees, the tibial cutting guide is secured to the linkage device (which know links between the femur and the tibia). Correct placement of this assembly will result in parallel tibial cut to the kinematic aligned femoral trial, restoring the native varus/valgus alignment. Slope is controlled by flexion, and increasing flexion will result in an increased slope. The tibial cutting guide is then attached to the tibia with two 3.2 mm threaded pins. The tibia is subluxed anteriorly (with or without the femoral component in place), level of resection is measured 10 mm from the highest point at the un-eroded tibial plateau or from base of the spines , the device is fixed to the tibia using a third 3.2 mm pin, and a standard tibial osteotomy is performed (*Figure 4*). Correct size of the tibial baseplate is chosen and the tibia is prepared to accept the component. A trial may be performed either using a spacer block or using trial components. Final components are then cemented into place.

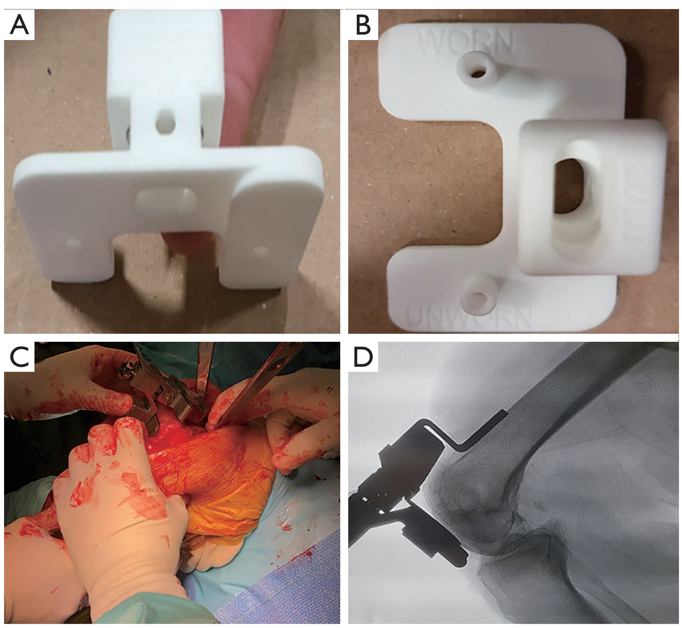

Figure 3 Distal femoral reference block corresponding to the cartilage erosion pattern (A,B). Anterior cortex referencing device connected to the distal cutting reference block (C) and paced flush on the anterior as shown by radiography (D).

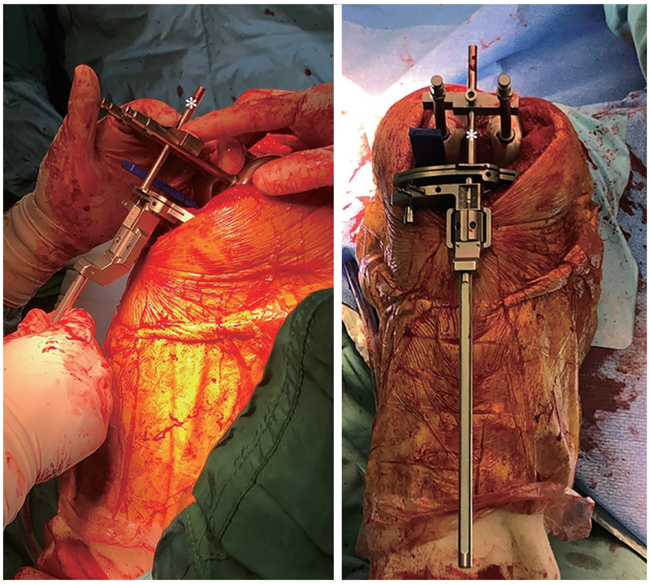

Figure 4 Linking the Femur to the tibia. The linkage device (*) is placed on the peg hole drills and connected distally to the tibial cutting guide.

Results

Overall, 146 patients were included in the study, of those 107 (73.3%) were female. The mean patient age was 70.5 (SD 7.7). Analyzing the 6 months post op OKS scores suggested a learning curve of approximately 20 patients as 7 of these patients (35%) had an OKS <30, while only 9 of the remaining 126 patients (7.1%) had scores below 30 (*Figure 5*).

Of the cohort 26 patients undergone a prior contralateral mechanically aligned TKA reported shorter recovery time, more natural feel and preferred the kinematic aligned knee over the mechanical aligned one (*Table 2*). When asked specifically with which knee they were more satisfied, 19 patients (73.1%) preferred the kinematic knee while only 7 (26.9%) preferred the mechanical one.

Discussion

The Main goal of this study is to present a novel technique for cutting the tibia while performing KA-TKA. The presented technique doesn't require a patient specific instrumentation. This Article introduce a simple reproducible approach for cutting the tibia which takes into account its relationship with the femur and is guided by native soft tissue tension without the need to make releases.

Kinematic knee alignment relies on restoring the joint to its prearthritic state. The fact that the femur in the majority of cases loses only cartilage and does not lose subchondral bone in the arthritic states (6,12) makes it somewhat easier to restore its original position. The tibial cut, on the other hand is more challenging as the arthritic process involves the subchondral bone in the majority of the cases (including compression and erosion), thus compensating only for cartilage loss will not always be enough. Previous instrumented techniques, including the use of an extramedullary tibial guide and navigation have been proposed (3). Others cut the tibia several times until reaching the appropriate soft tissue tensioning which is determent by neglectable varus/valgus laxity in extension using a spacer block after initial "eye bole" osteotomy. The main issue with this technique is that it may not be reproducible in average surgeon hands, and may be very difficult for surgeons that lack experience or those that are just starting to adopt the technique. Lack of reproducibility may also lead to different outcomes from a research standpoint. Using navigation may be technically easier and may help with reproducibility, however it is not yet widely available, it increases operative time, and increases cost, as well as lacks the ability to fill the soft tissue envelope.

The "linked technique" that we describe takes into account the relationship between the femur and tibia, and is guided by soft tissue, resulting in the recreation of native alignment and native soft tissue laxity. The technique we present, and the instruments used are intentioned to make kinematic alignment arthroplasties more intuitive, simple and reproducible.

The proposed technique has several pitfalls that need to be taken into consideration. First, before performing the femoral cut, one must make sure that the extramedullary guide sits flush on the anterior femoral cortex and that the cutting block is well connected to it and sits in close contact to the distal femur. This will help avoid flexion or extension in the sagittal plane. Second, proper shim placement is crucial and the obliquity of the tibial plateau may sometimes lead to subluxation or dislocation of it, which may in turn affect the coronal alignment. In these cases, removal of cartilage/subchondral bone from the tibial plateau will allow for proper placement of the shim and reduce subluxations/dislocations of it to the medial/lateral gutter. Finally, care should be taken when fixating the tibial cutting guide to make sure that the entire construct femur-linkage-tibia did not lose position and that the slope has not changed. Coronal and sagittal alignment need to be examined

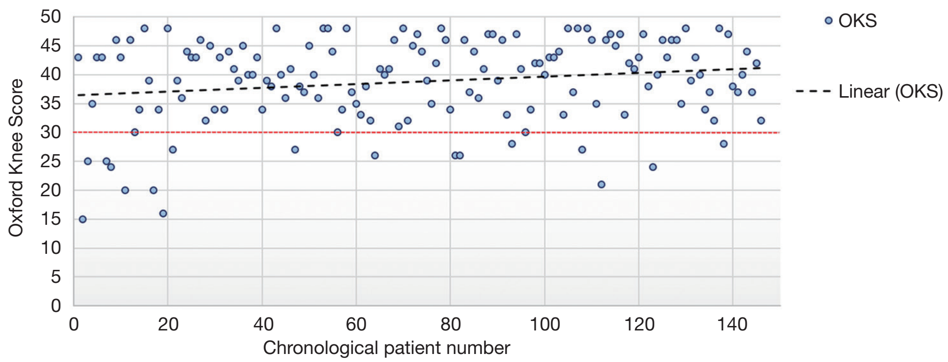

Figure 5 Oxford Knee Scores of the first 146 cases undergoing kinematic TKA using the "linked technique", presented by the chronological order of surgery. TKA, total knee arthroplasty.

Table 2 Specific questions comparing rehabilitation, native feel, activity level and satisfaction in 26 patients who had undergone bilateral knee arthroplasties, once by mechanical alignment and once by kinematic alignment

Question	Kinematic (%)	Mechanical (%)	No difference (%)
With which knee was the rehab less painful?	17 (65.4)	4 (15.4)	5 (19.2)
With which knee was return to normal activity faster?	17 (65.4)	2 (7.7)	7 (26.9)
With which knee are you more satisfied?	19 (73.1)	7 (26.9)	0 (0)
Which leg requires less effort for 200 meters walk?	4 (15.4)	2 (7.7)	20 (76.9)

following each pin is placed into the tibia and before the tibial cut is performed.

Our paper has some drawbacks. Even though we start looking at some difference between the two, it wasn't fully compared to the conservative mechanically techniques. The presented technique hasn't been compared to other kinematic techniques. Another aspect that hasn't been examined to this point is the postoperative multiplanar correct component positioning and physiological movement. Further research is required in order to address the issues above.

Taking the above limitations into consideration, we present a novel technique for performing kinematic knee alignment that is guided by soft tissue and does not require patient specific instrumentation, which has shown preliminary satisfaction in patients who had prior MA-TKA in their other knee. This should aid less experiences surgeons and those switching from cutting the bone perpendicular to the mechanical axis, in their transition to kinematic aligned arthroplasties.

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Footnote

Conflict of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/aoj.2019.08.03). Bar-Ziv Y reports his involvement in the development of the linkage device that was used in the presented technique. AG reports his role as an Unpaid consultant for Active Inplants, his role on the Board or committee member of the International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine. He also reports his stocks or stock options in APOS Medical & Sports Technologies Ltd, all of which outside the submitted work. BNEreports grants from EFORT FOUNDATION CLINICAL RESEARCH FELLOWSHIP, outside the submitted work. The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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