160

Kinematically Aligned Total Knee Arthroplasty

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OVERVIEW

Kinematically aligned total knee arthroplasty (TKA) has gained interest because two randomized trials and a national multicenter study showed that patients treated with kinematic alignment reported significantly better pain relief, function, flexion, and a more normal feeling knee than mechanical alignment with a similar implant survivorship at 2, 3, and 6 years.[4,8,17,18,26] This chapter introduces the three goals of kinematically aligned TKA: (1) restore the native tibial-femoral articular surfaces, (2) restore the native knee and limb alignments, and (3) restore the native laxities of the knee. Because kinematically aligned TKA is relatively new and is not as well understood as mechanically aligned TKA, the technique and quality assurance steps for kinematically aligning the femoral and tibial components to the native tibial-femoral articular surface are detailed. Examples of patients with severe varus and valgus deformity and flexion contractures treated with kinematically aligned TKA are shown. Surgical considerations for performing kinematically aligned TKA in the knee with an incompetent posterior cruciate ligament and fixed valgus deformity are discussed. Finally, studies describing the similarities and differences of the function, limb, knee, and tibial component alignment, and survivorship between the kinematically and mechanically aligned TKA are presented.

GOAL ONE: RESTORE THE NATIVE TIBIAL-FEMORAL ARTICULAR SURFACES

One goal of kinematically aligned TKA is to set the anterior-posterior, proximal-distal, and medial-lateral translation and flexion-extension, varus-valgus, internal-external rotation (6 degrees-of-freedom) of the femoral and tibial components to restore the native tibial-femoral articular surface of the knee. Setting the femoral and tibial components on the native tibial-femoral articular surface coaligns the axes of the components as close as possible with the three kinematic axes of the normal knee[8,10,19] (Fig. 160.1). One kinematic axis is the flexion axis of the tibia. This axis penetrates the two centers of the circular portion of the posterior femoral condyles from about 20 to 120 degrees, like an axle passing through two wheels, and determines the native arc of flexion and extension of the tibia on the femur.[10,14,22,30,35] The second kinematic axis is the flexion axis of the patella. This axis lies parallel to the flexion axis of the tibia, averages 10 mm anterior and 12 mm proximal to the flexion axis of the tibia, and determines the native arc of flexion and extension of the patella on the femur.[6,21] The flexion-extension plane of the extended knee lies perpendicular to these two kinematic axes in the center of the knee. The third kinematic axis is the longitudinal rotational axis of the tibia. This axis lies approximately perpendicular to the flexion axes of the tibia and patella and determines the native arc of internal and external rotation of the tibia on the femur.[6,14] These kinematic axes are closely parallel or perpendicular to the native tibial-femoral articular surface.* Therefore, a change in the position of either component in one or more of the 6 degrees of freedom changes the native tibial-femoral articular surfaces. A change in the native articular surface malaligns the rotational axes of the components with the three kinematic axes of the knee, which changes the native resting length of the collateral, retinacular, and posterior cruciate ligaments. Changing the native resting length of these ligaments causes unnatural tightening and/or slackening of the ligaments and unnatural tibial-femoral and patella-femoral motions that patients may perceive as pain, binding, stiffness, or instability.[10,13,14,31]

GOAL TWO: RESTORE THE NATIVE KNEE AND LIMB ALIGNMENTS

The second goal of kinematically aligned TKA is to restore the native knee and limb alignments.[13,18-20] Several studies support correction to the native or "constitutional" alignment when performing TKA as opposed to restoring mechanical alignment to neutral (Fig. 160.2).[13,23,33,34] Restoring mechanical alignment to native in patients with constitutional varus and valgus alignment is unnatural, and causes greater strain deviations in the medial and lateral collateral ligaments from the native knee.[1,7,13,23] Patients with preoperative varus have better clinical and functional outcome scores and the same implant survivorship at 7 years when the alignment is left in mild varus, as compared with patients overcorrected to neutral.[33] At a mean of 6 years after kinematically aligned TKA, restoration of the native alignments of the knee, limb, and tibia did not adversely affect implant survival and resulted in high function, which supports the consideration of kinematic alignment as an alternative to mechanical alignment when performing primary TKA.[18]

Current evidence suggests that the native alignment of the limb does not cause osteoarthritis of the knee. The clinical findings of bilateral osteoarthritis with a varus deformity in one

*References 6, 10, 11, 14, 16, and 21.

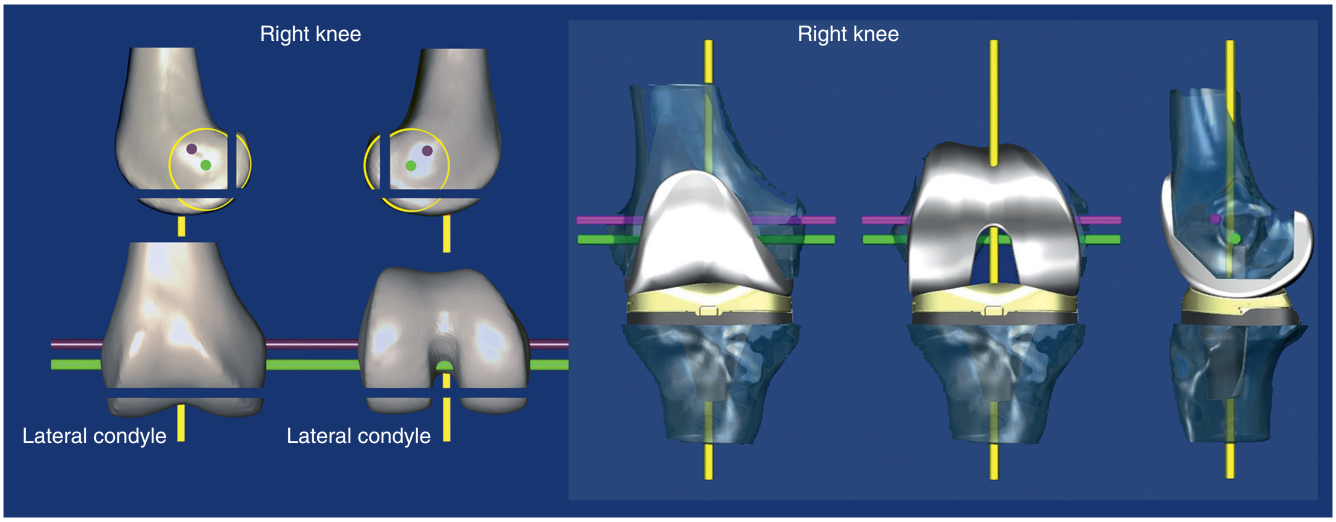

FIG 160.1 A right femur *(left)* and kinematically aligned TKA *(right)* shows the relationships between the three kinematic axes of the knee and the joint lines of the distal and posterior femoral resections and the 6 degrees-of-freedom position of the components. The flexion axis of the tibia is the *green line*, the flexion axis of the patella is the *magenta line*, and the longitudinal rotational axis of the tibia is the *yellow line*. All three axes are closely parallel or perpendicular to the joint lines. The flexion-extension plane of the extended knee is perpendicular to the flexion axes of the tibia and patella and is centered in the knee. Compensating for wear and kerf and resecting bone from the distal and posterior femur condyles by an amount equal in thickness to the condyles of the femoral component kinematically aligns the femoral component by coaligning the axis of the femoral component with the flexion axis of the tibia, assuming that the condyles of the femoral component are symmetric in the flexion-extension plane of the tibia. (From Howell SM, Papadopoulos S, Kuznik KT, Hull ML: Accurate alignment and high function after kinematically aligned TKA performed with generic instruments. *Knee Surg Sports Traumatol Arthrosc* 21(10):2271–2280, 2013.)

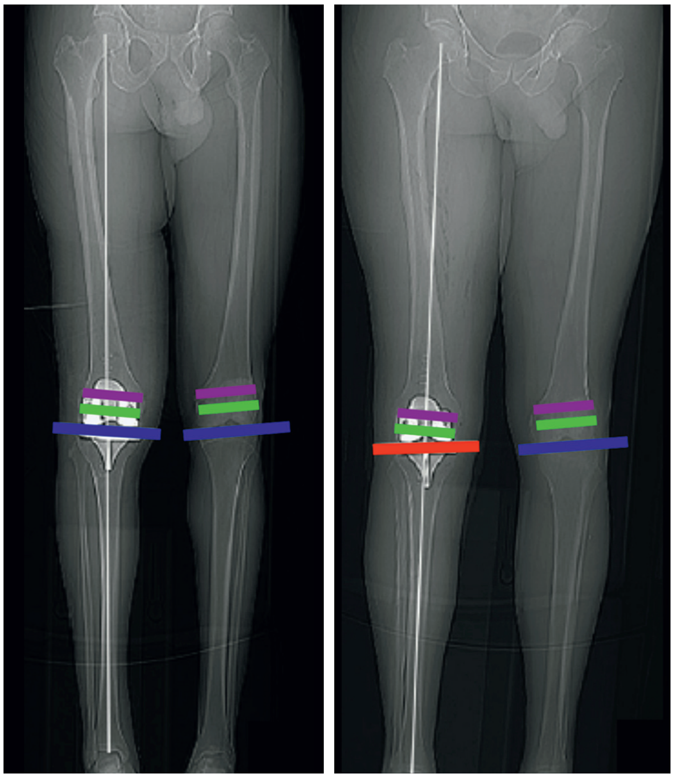

FIG 160.2 This composite shows that (1) the kinematically aligned TKA *(left patient)* restores the native tibial-femoral joint surface *(blue line)* and the native limb alignment *(white line)*. The axes of the femoral component are coaligned with the flexion axes of the tibia *(green line)* and patella *(magenta line)*. (2) The mechanically aligned TKA *(right patient)* changes the native tibial-femoral joint surface *(red line)*, the native limb alignment, and malaligns the axes of the femoral component oblique to the flexion axes of the tibia and patella. Studies have shown that kinematic alignment creates fewer varus limb and varus knee outliers and has the same average limb and knee alignment as mechanical alignment. (From Dossett HG, Estrada NA, Swartz GJ, et al: A randomised controlled trial of kinematically and mechanically aligned total knee replacements: two-year clinical results. *Bone Joint J* 96-B(7):907–913, 2014; Dossett HG, Swartz GJ, Estrada NA, et al: Kinematically versus mechanically aligned total knee arthroplasty. *Orthopedics* 35(2):e160–e169, 2012; Nunley RM, Ellison BS, Zhu J, et al: Do patient-specific guides improve coronal alignment in total knee arthroplasty? *Clin Orthop* 470(3):895–902, 2012.)

knee and a valgus deformity in the other (“wind-swept”), and the lack of osteoarthritis in most older adult Asian patients with severe constitutional varus, suggest that native alignment plays little role in the development of osteoarthritis. Instead, the onset of osteoarthritis is associated with known changes in cartilage metabolism that occur with aging. Articular cartilage is a mechanosensitive tissue that, when healthy, increases anabolic activity and thickens when loaded. Chondrocytes experience age-related declines in their anabolic activity and thickening response and cause osteoarthritis because the ability to respond to and compensate for high loads from activity and obesity is gradually lost.[2]

GOAL THREE: RESTORE THE NATIVE LAXITIES OF THE KNEE

The third goal of kinematically aligned TKA is to restore the native laxities of the knee, which are tighter at 0 degrees of flexion than at 45 and 90 degrees of flexion (Fig. 160.3).[31,32] At 0 degrees of flexion, the native tibia-femoral joint behaves as a rigid body because the average varus (0.7 degrees), valgus (0.5 degrees), internal (4.6 degrees), and external (4.4 degrees) rotations of the tibia on the femur are negligible under applied loads that just engage the soft tissue restraints.[12,31,32] At 45 degrees and 90 degrees of flexion, the mean laxity is fivefold greater in varus (3.1 degrees) rotation; fourfold greater in distraction; threefold greater in valgus (1.4 degrees), internal (14.6 degrees), and external (14.7 degrees) rotation; and twofold greater in anterior translation than at 0 degrees of flexion.[31,32] The maintenance of these native differences in laxities between positions of knee flexion requires the maintenance of the native resting lengths of the collateral ligaments, posterior cruciate ligament, and retinacular ligaments. The alignment goal of gap balancing a TKA overtightens the laxities of the flexion gaps at 45 and 90 degrees of flexion to match those at 0 degrees of flexion, which patients may perceive as pain, stiffness, and/or limited flexion.[10,31]

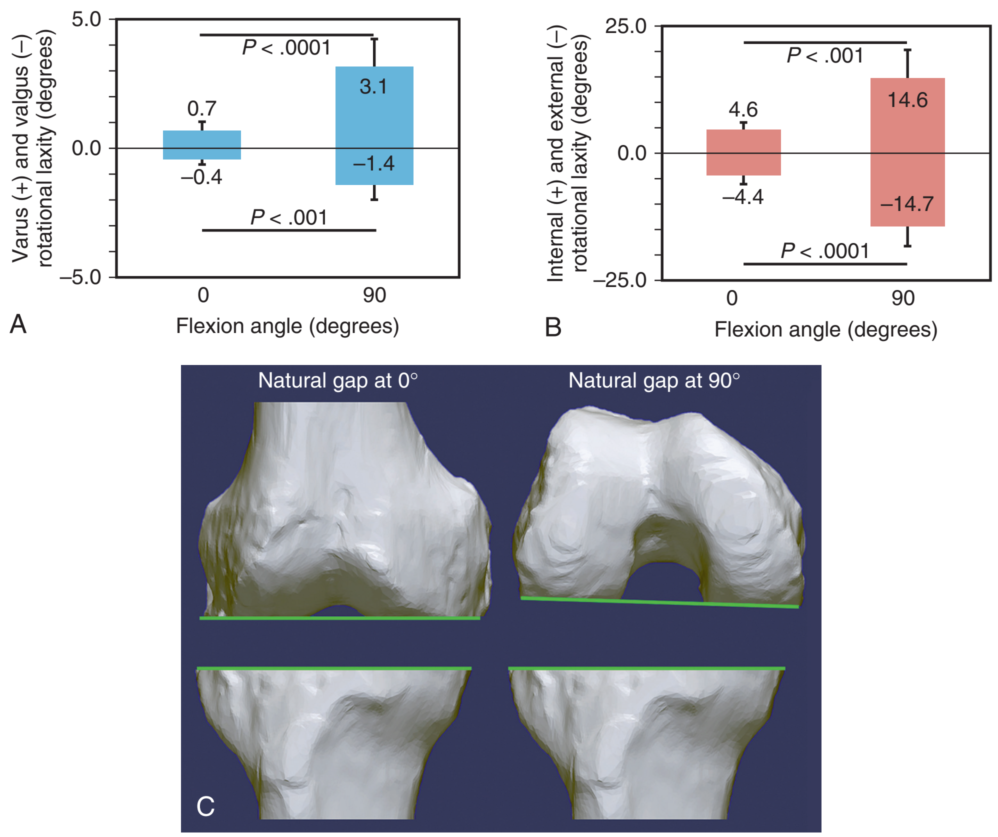

FIG 160.3 This composite shows column graphs of the native varus (+), valgus (–), internal (+), and external (–) rotational laxities of the normal knee at 0 and 90 degrees of flexion (A and B), and the native gaps of a right knee at 0 and 90 degrees of flexion after making the resections using kinematic alignment (C). The paired columns connected by a *P*-value of less than 0.05 indicate that the laxity at 90 degrees is greater than at 0 degrees of flexion. The resected right knee shows a symmetrically shaped gap that is equal medially and laterally at 0 degrees of flexion, and an asymmetrically shaped gap that is smaller medially than laterally at 90 degrees of flexion. Therefore, the surgical goal of gap balancing a TKA overtightens the flexion gap. Error bars show ±1 standard deviation. (From Roth JD, Howell SM, Hull ML: Native knee laxities at 0 degrees, 45 degrees, and 90 degrees of flexion and their relationship to the goal of the gap-balancing alignment method of total knee arthroplasty. *J Bone Joint Surg Am* 97(20):1678–1684, 2015; Roth JD, Hull ML, Howell SM: Rotational and translational limits of passive motion are both variable between and unrelated within normal tibiofemoral joints. *J Orthop Res* 33(11):1594–1602, 2015.)

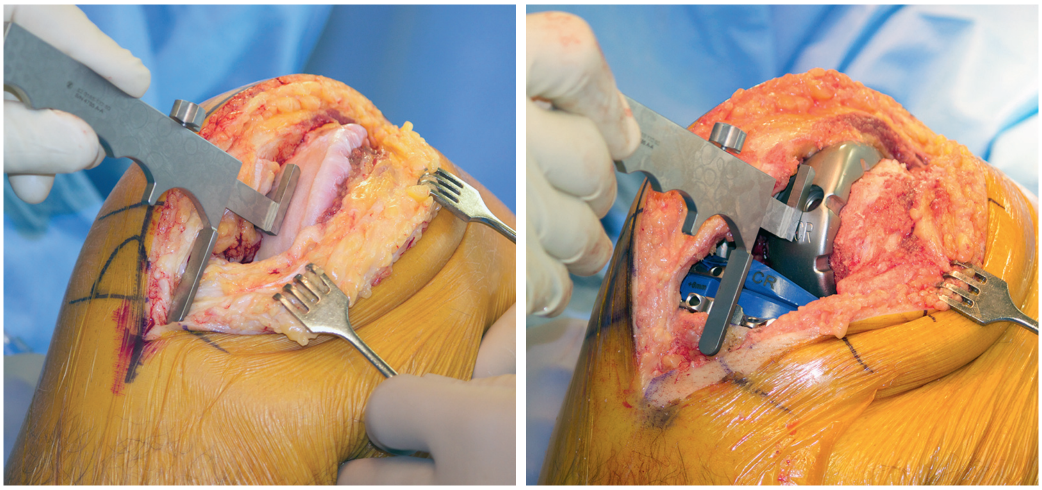

FIG 160.4 Intraoperative photographs of a right knee with a varus deformity in 90 degrees of flexion shows the measurement of the native anterior offset of the tibia from the worn distal medial articular surface of the femur in a knee at the time of exposure *(left)* and at the time of reduction with the trial components *(right).* The laxities of the knee in 90 degrees of flexion are restored by first compensating 2 mm for cartilage wear on the distal medial femur. The anterior-posterior slope and the thickness of the tibial component are adjusted until the offset of the anterior tibia from the distal medial femoral condyle with the trial components matches that of the knee at the time of exposure. Finally, the internal and external rotations of the tibia are set to approximately 14 degrees.

Restoring the native knee laxities at 0 degrees of flexion requires removal of all osteophytes, extending the knee to 0 degrees, and adjusting the varus-valgus angle and thickness of the tibial component until the varus, valgus, internal, and external rotational laxities are negligible.[19] To restore the native laxities of the knee at 90 degrees of flexion, begin by flexing the knee to 90 degrees. Adjust the anterior-posterior slope and thickness of the tibial component until the offset of the anterior tibia from the distal medial femoral condyle, measured at the time of exposure, matches the knee with the trial components, and the internal and external rotation of the tibia approximate 14 degrees (Fig. 160.4).[19] The kinematically aligned TKA can restore native knee and limb alignments and resolve knee laxity issues. A randomized clinical trial and a national multicenter study showed patients with a kinematically aligned TKA reported better pain relief, better function, better flexion, and a more normal feeling knee than patients with a mechanically aligned TKA.[8,26]

TECHNIQUE AND QUALITY ASSURANCE STEPS FOR MINIMIZING FLEXION AND KINEMATICALLY ALIGNING THE FEMORAL COMPONENT TO THE NATIVE ARTICULAR SURFACE

Kinematic alignment sets the femoral component at the native angle and the level of the distal (0 degrees) and posterior (90 degrees) joint line. The surgical technique begins by using an offset caliper to measure the anterior-posterior offset of the anterior tibia from the distal medial femur with the knee in 90 degrees of flexion (see Fig. 160.4). Two millimeters are subtracted from the offset measurement cartilage that is missing on the distal medial femoral condyle. Once the knee is fully exposed, the locations of cartilage wear are assessed on the distal femur. A ring curette is used to remove any partially worn cartilage to bone. The flexion-extension position of the femoral component is set by the insertion of a positioning rod 8 to 10 cm through a drill hole placed parallel to the anterior surface of the distal femur and perpendicular to the distal articular surface (Fig. 160.5). The varus-valgus rotation and proximal-distal translation of the femoral component are set by using a disposable distal referencing guide that compensates 2 mm when there is cartilage wear on the distal medial femoral condyle in the varus knee, and 2 mm when there is cartilage wear on the distal lateral femoral condyle in the valgus knee. The anterior-posterior translation and internal-external rotation of the femoral component are set by placing a 0-degree rotation posterior referencing guide in contact with the posterior femoral condyles (Fig. 160.6). The positioning of the posterior referencing guide rarely requires correction because complete cartilage loss is uncommon on the posterior medial and posterior lateral femoral condyles in most varus and valgus osteoarthritic knees. Correction for bone wear is rarely needed at 0 and 90 degrees of flexion, even in the most arthritic knees.[19,25]

The first intraoperative quality assurance step checks that flexion of the femoral component is minimized by positioning the starting hole for the positioning rod midway between the top of the intercondylar notch and aligning the positioning rod parallel to the anterior cortex of the femur (see Fig. 160.5). The second intraoperative quality assurance step checks that the femoral component is kinematically aligned to the native femoral articular surface. A caliper measurement of the thickness of the distal and posterior femoral resections that adjust the thicknesses within ±0.5 mm of the thickness of the condyles of the femoral component is performed after compensating for cartilage wear and kerf (see Fig. 160.6). Alignment references used to position the femoral component in mechanically aligned TKA, such as the femoral mechanical axis, intramedullary canal,

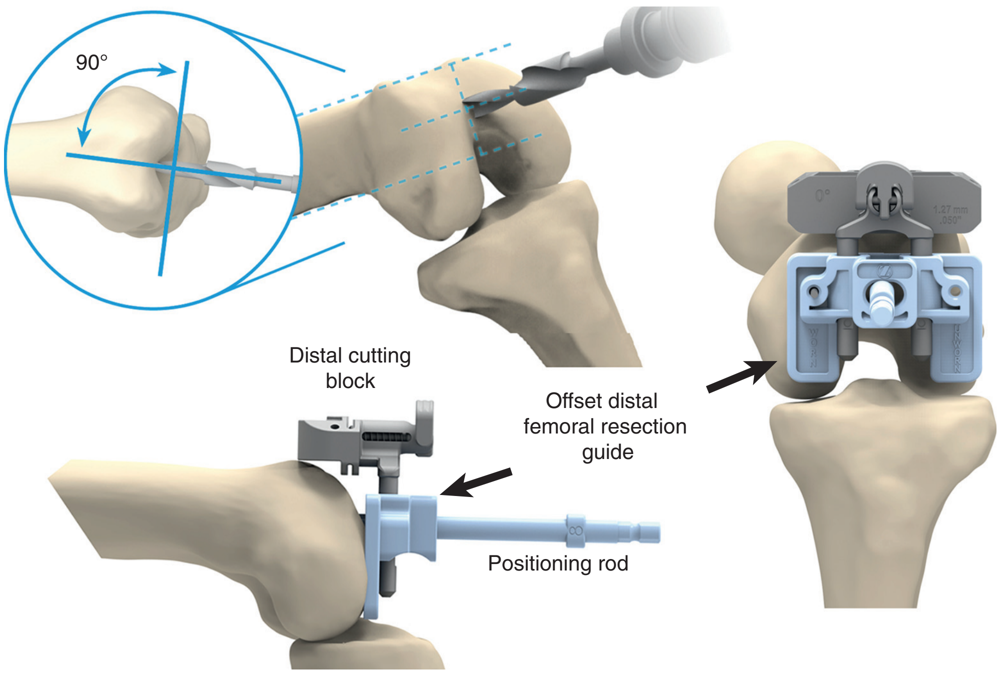

FIG 160.5 This composite shows the method of setting the flexion-extension and varus-valgus rotations and the proximal-distal translation of the kinematically aligned femoral component with disposable instruments *(blue)*. The insertion of a positioning rod 8 to 10 cm through a hole drilled midway between the top of the intercondylar notch and the anterior cortex, parallel to the anterior surface, and perpendicular to the distal articular surface of the distal femur sets the flexion-extension rotation of the femoral component. The distal cutting block is inserted into the offset distal femoral resection guide. This assembly compensates for 2 mm of cartilage wear on the worn condyle(s) and is placed over the positioning rod, in contact with the distal femur, and sets varus-valgus rotation and proximal-distal translation of the femoral component.

transepicondylar axis, and anterior-posterior axis, are not of interest or of use when performing kinematically aligned TKA.[10,11,13,18,19]

TECHNIQUE AND QUALITY ASSURANCE STEPS FOR ALIGNING THE TIBIAL COMPONENT TO THE NATIVE ARTICULAR SURFACE

Kinematically aligned TKA sets the tibial component at the native internal-external, varus-valgus, flexion-extension, and proximal-distal positions of the articular surface of the tibia. The internal-external rotation can be set to the major axis of the lateral tibial condyle or by using a kinematic tibial baseplate method.[19,27,28] The varus-valgus, flexion-extension, and proximal-distal positions are set using an extramedullary tibial guide (Figs. 160.7 to 160.9).[19] The preferred method for setting the internal-external rotation of the tibial component is chosen. When the major axis of the lateral tibial condyle method is used, the elliptically shaped boundary of the articular surface of the lateral tibial condyle is identified and the major axis is drawn (see Fig. 160.7).[19,27,28] A guide is used to drill two holes into the medial articular surface, parallel to the major axis drawn on the lateral tibial condyle. After the tibial resection is made, the anterior-posterior axis of the tibial component is aligned parallel to these two holes using a rationale similar to the Cobb method, which finds the flexion-extension plane of the knee by fitting circles to the medial and lateral tibial condyles.[5] In mechanically aligned TKA, the medial border and medial one-third of the tibial tubercle are considered useful landmarks. In contrast, a study of a case series of kinematically aligned TKAs showed that aligning the tibial component to the medial border or medial one-third of the tibial tubercle would have malrotated the tibial component 5 degrees or more from the flexion-extension plane of the knee in 70% and 86% of the knees, respectively.[3,15,19] The use of the major axis of the lateral tibial condyle is a reproducible method, as shown by negligible bias (−1 degree internal) and acceptable precision (±5.4 degrees) between the anterior-posterior axis of the tibial component and the flexion-extension plane of the knee, and minimal malrotation of the tibial component on the femoral component.[27,28] Next, a conventional extramedullary tibial resection guide is applied to the ankle and an angel wing is placed in the saw slot of the guide (see Fig. 160.8). The varus-valgus position of the tibial component is set by medially translating the slider at the ankle of the guide until the saw slot is parallel to the tibial articular surface after visual compensation for cartilage and bone wear. The flexion-extension or slope of the tibial component is set by adjusting the inclination of an angel wing placed in the saw slot until it is parallel to the slope of the medial joint line. The proximal-distal translation of the tibial component is set by adjusting the level of the saw slot until the 10-mm tibial resection gauge contacts the center of the unworn tibial condyle.[19] A conservative tibial resection is made while

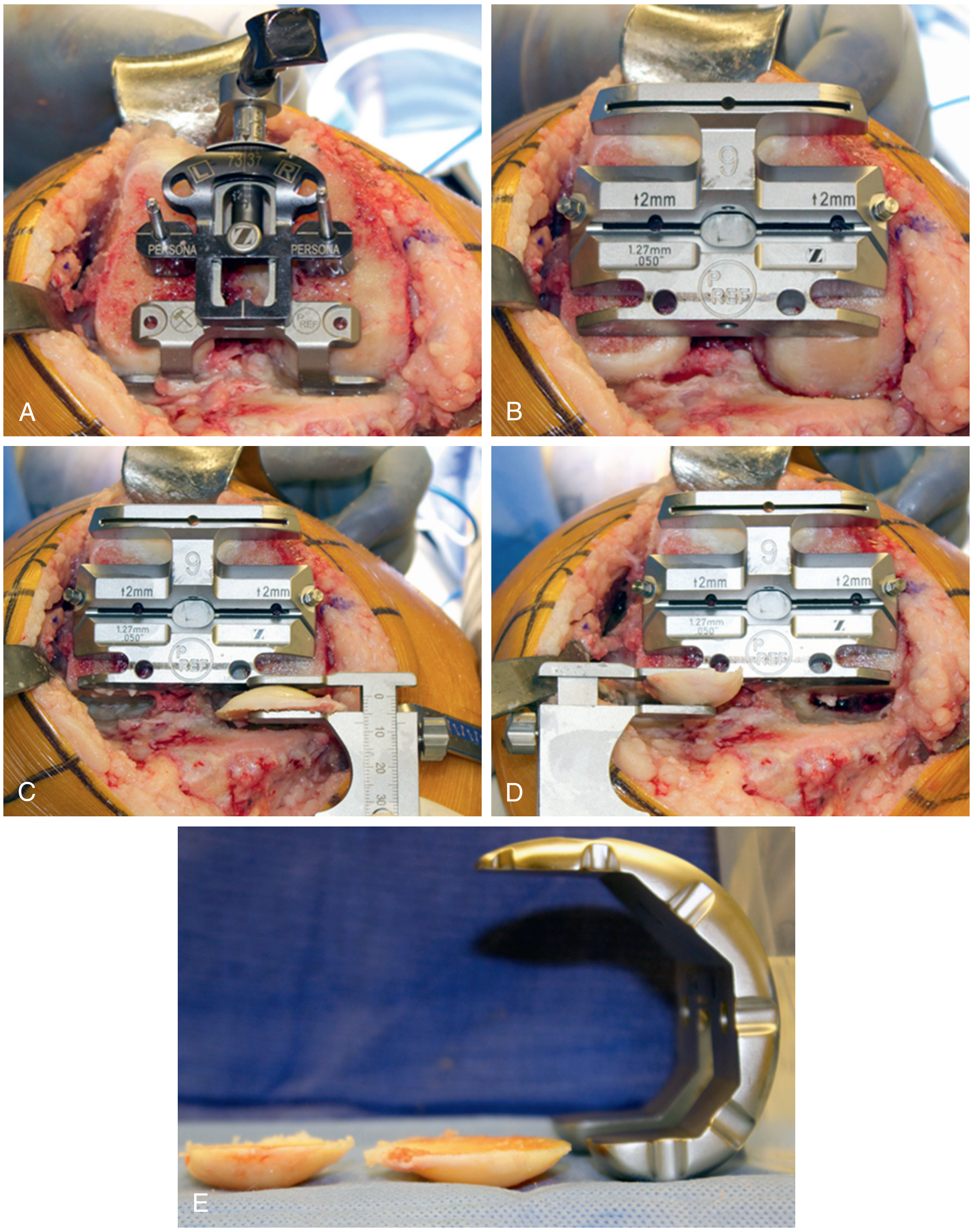

FIG 160.6 This composite of a right varus osteoarthritic knee shows the steps for kinematically aligning the femoral component at 90 degrees of flexion. A 0-degree rotation posterior referencing guide is inserted in contact with the posterior femoral condyles and pinned (A). The correct size chamfer guide is inserted into the pinhole (B). A caliper measures the thickness of the posterior medial femoral condyle (C) and posterior lateral femoral condyle (D). These steps set internal-external rotation and anterior-posterior translation of the femoral component to the native articular surface of the posterior femur (E).

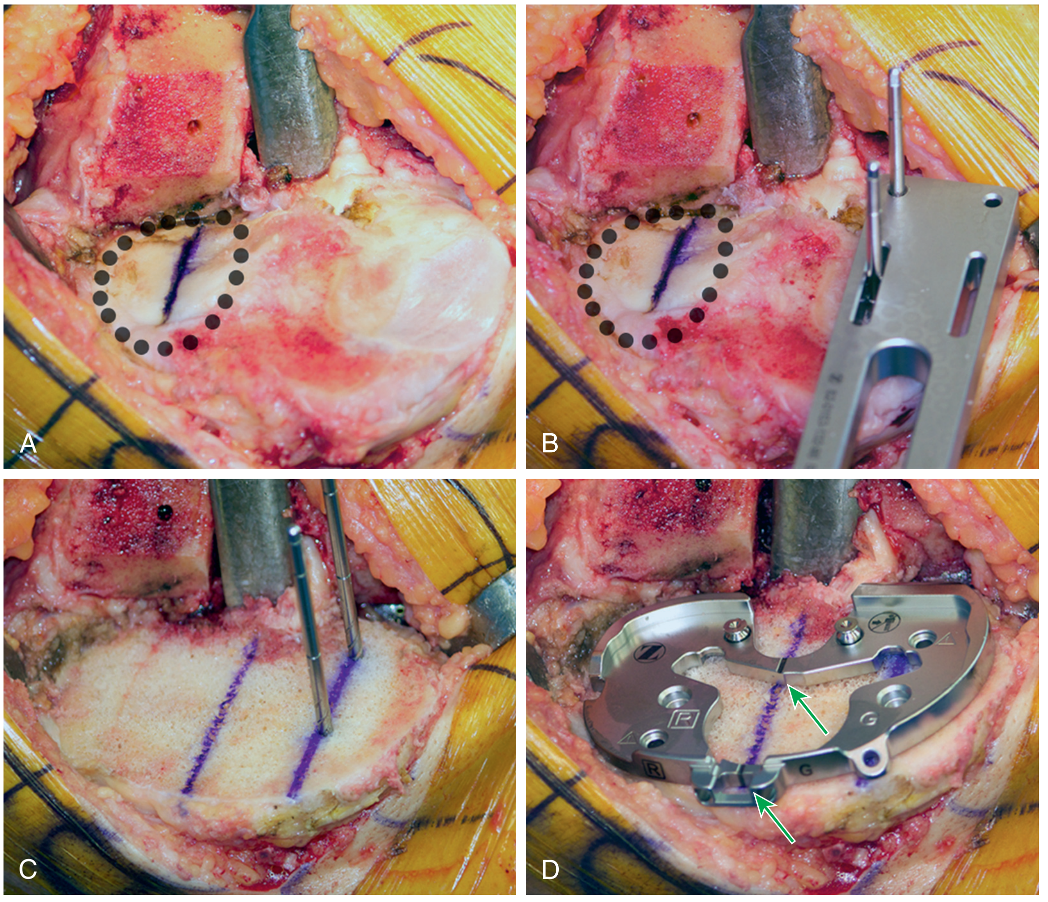

FIG 160.7 This composite of a right knee shows the major axis of the lateral tibial condyle method for kinematically aligning the internal-external rotation of the trial tibial component to the anterior-posterior axis *(blue line)* of the almost elliptically shaped boundary of the articular surface of the lateral tibial condyle *(black dots)* (A). A guide is used to drill two pins through the medial tibial articular surface and parallel to the major axis (B). The tibial articular surface is resected and removed, the two drill holes are identified (pins), and lines parallel to the drill holes are drawn (C). The score marks *(green arrows)* indicate that the anterior-posterior axis of the trial tibial baseplate is aligned parallel to these lines (D).

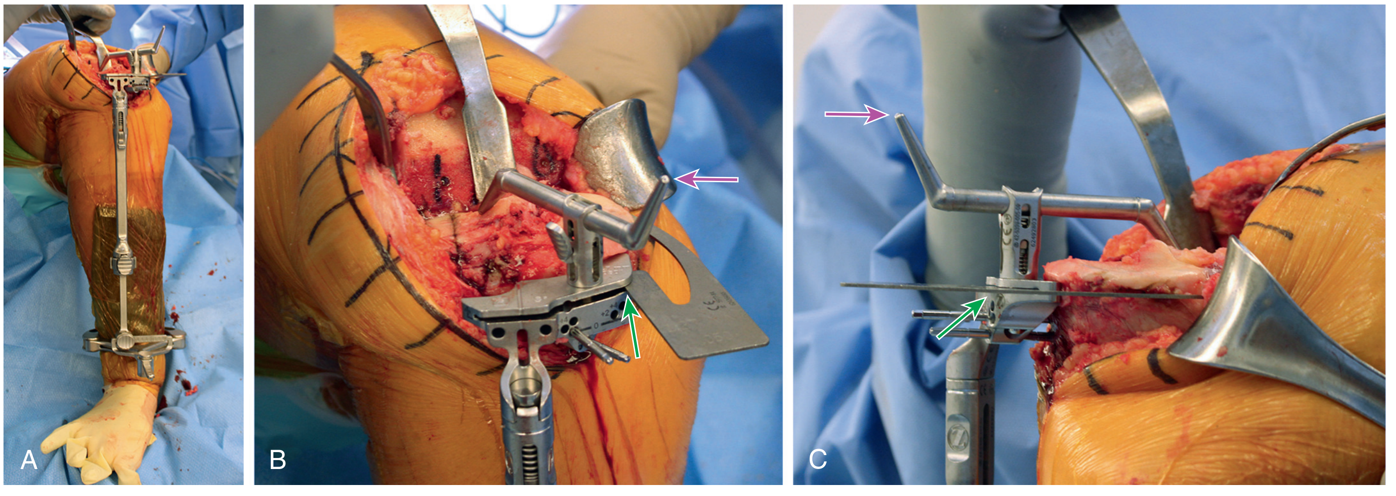

FIG 160.8 This composite of a right knee shows the steps for kinematically aligning the tibial component. A conventional extramedullary tibial resection guide with a 10-mm offset tibial resection gauge *(magenta arrow)* and angel wing *(green arrow)* is applied to the ankle (A, B, and C). The varus-valgus position of the tibial resection is set by adjusting the medial-lateral position of the slider at the ankle end of the guide until the saw slot is parallel to the tibial articular surface after visually compensating for cartilage and bone wear. The proximal-distal translation of the tibial component is set by adjusting the level of the saw slot until there is contact between the 10-mm offset tibial resection gauge and the center of the unworn tibial condyle (B). The flexion-extension rotation of the tibial component is set by adjusting the inclination of the angel wing parallel to the slope of the medial joint line (C). These steps set the proximal-distal translation and the varus-valgus and flexion-extension rotations of the tibial component parallel to the native articular surface of the tibia.

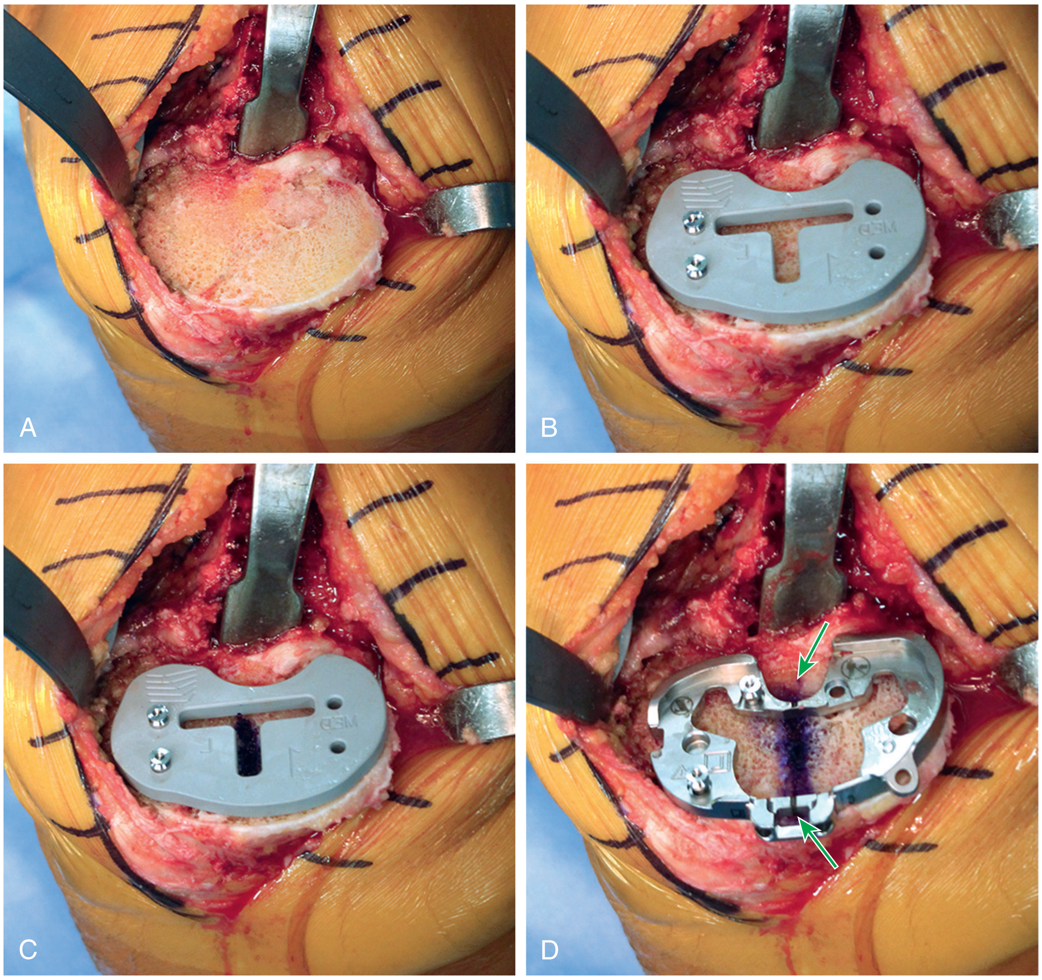

FIG 160.9 This composite of a right knee shows the steps for aligning the internal-external rotation of the trial tibial component parallel to the flexion-extension plane of the knee with a kinematic tibial baseplate *(gray)*. The cortical contour of the anatomic resection of the tibia is shown (A). The largest size kinematic tibial baseplate that fits within the contour is selected from the seven kinematic tibial baseplates and is fit within the cortical contour (B). The anterior-posterior axis of the kinematic tibial baseplate is marked *(blue line)* (C). The score marks *(green arrows)* indicate that the anterior-posterior axis of the trial tibial baseplate is aligned parallel to the *blue line* (D).

protecting the insertion of the posterior cruciate ligament. When the kinematic tibial baseplate is used to set internal-external rotation of the tibial component, the largest of the seven available sizes that fits within the cortical contour of the tibial resection is selected and best fit to the anterior and medial cortical edge (see Fig. 160.9). The in vitro reproducibility of the kinematic tibial baseplate was evaluated on 166 tibial resections by five arthroplasty surgeons, three orthopedic surgery fellows/residents, and three students, and showed a negligible bias (0.7 degrees external) and acceptable precision (±4.6 degrees) between the anterior-posterior axis of the kinematic tibial baseplate and the flexion-extension plane of the knee. The in vivo reproducibility was evaluated in 63 kinematically aligned TKAs by one arthroplasty surgeon and showed a negligible bias (0.2 degrees external) and an acceptable precision (±3.6 degrees) between the anterior-posterior axes of the tibial and the femoral components (unpublished study).

The third intraoperative quality assurance step checks that the internal-external rotation of the tibial component is parallel to the flexion-extension plane of the knee by using the major axis of the lateral tibial condyle or the kinematic tibial baseplate method.

The fourth intraoperative quality assurance step checks that the varus-valgus rotation of the tibial component restores the native tibial joint line by adjusting the varus-valgus of the tibial resection to minimize varus-valgus laxity and to restore the native knee and limb alignments with the knee at 0 degrees of flexion.[19,27,28,31]

The fifth and final quality assurance step checks that the flexion-extension or slope of the tibial component restores the native tibial joint line. The flexion-extension of the tibial resection is adjusted to restore the anterior offset of the anterior tibia from the distal medial femoral condyle. This adjustment is accomplished with trial components that are comparable to that of the knee at the time of exposure and that restore approximately 14 degrees of internal-external rotation of the tibia on the femur with the knee in 90 degrees of flexion (see Fig. 160.4).[19,28,31] Alignment references used to position the

Step-wise algorithm for balancing KA TKA

Tight in flexion and extension	Tight in flexion and well-balanced in extension	Tight in extension and well-balanced in flexion	Well-balanced in extension and loose in flexion	Tight medial and loose lateral in extension	Tight lateral and loose medial in extension
Use thinner liner Recut tibia and remove more bone	Increase posterior slope until natural A-P offset is restored at 90° of flexion	Remove posterior osteophytes Reassess Strip posterior capsule	Add thicker liner and recheck knee extends fully When knee does not fully extend check PCL tension When PCL is incompetent consider PS implants or UC liner	Remove medial osteophytes Reassess Recut tibia in 2° more varus Insert 2 mm thicker liner	Remove lateral osteophytes Reassess Recut tibia in 2° more valgus Insert 2 mm thicker liner

FIG 160.10 The table shows a stepwise algorithm for balancing the kinematically aligned TKA. The top row lists six malalignments, and the bottom lists the corresponding corrective actions. Notice that the corrections that require a recut of bone are performed by fine-tuning the proximal-distal translation and the varus-valgus and flexion-extension (slope) rotations of the tibial resection and not by recutting the femur. *A-P,* Anterior-posterior; *KA,* kinematic alignment; *PCL,* posterior cruciate ligament; *PS,* posterior stabilized; *TKA,* total knee arthroplasty; *UC,* ultra congruent.

tibial component in mechanically aligned TKA, such as the tibial mechanical axis, intramedullary canal, posterior condylar axis, and tibial tubercle, are not of interest or of use when performing kinematically aligned TKA.[†]

When any of these conditions is not met, a stepwise alignment algorithm determines the corrective actions to achieve kinematic alignment (Fig. 160.10). The underlying principle of this algorithm is that the corrections requiring a recut of bone are performed by fine-tuning the varus-valgus, flexion-extension or slope, and proximal-distal positions of the tibial resection, and not by recutting the femur.

MANAGING THE KNEE WITH AN INSUFFICIENT POSTERIOR LIGAMENT OR SEVERE FIXED VALGUS DEFORMITY

There are special considerations when performing kinematically aligned TKA in the patient with an insufficient posterior cruciate ligament (Fig. 160.11) and severe fixed valgus deformity (Fig. 160.12). There are three potential corrective actions when there is a chronic posterior cruciate ligament tear or an insufficiency is discovered after resecting the femur (see Fig. 160.11). One corrective action is to use a narrow version of a 2-mm larger posterior stabilized femoral component when the implant design permits this adjustment. The larger posterior stabilized femoral component is cemented contacting the anterior resection of the femur and the 2-mm gaps between the posterior resections and femoral component are filled with cement. This maintains the level of the distal joint line and compensates for the 2- to 3-mm increase in the flexion gap caused by the insufficiency of the posterior cruciate ligament. The second action is to use an ultracongruent tibial liner when the flexion gap is not excessive. The third is to resect an additional 2 mm from the distal femur and use a 2-mm thicker liner. This approach requires the surgeon to accept that raising the distal and posterior femoral joint line 2 mm violates the kinematic alignment goal of restoring the native tibial-femoral articular surfaces.

We estimate that 15% of fixed valgus deformities remain in 2 to 3 degrees of excessive valgus deformity after adjusting the varus-valgus angle and thickness of the tibial component until the varus-valgus laxity is negligible with the knee to 0 degrees of flexion (see Fig. 160.12). In this small subset of valgus knees, we perform a careful lengthening of the lateral collateral ligament 2 to 3 mm via the pie-crusting technique with a spinal needle, with distraction applied with a laminar spreader to the lateral compartment with the knee in 90 degrees of flexion (Fig. 160.13). After completing the lengthening, a recut guide is used to cut the tibia in 2 to 3 degrees more varus, and a 2-mm thicker liner is inserted. For a tibia of normal length, each degree of varus or valgus correction at the knee joint causes a 6- to 7-mm medial or lateral translation of the ankle. Therefore, a 3-degree varus correction at the knee causes an 18- to 21-mm medial translation at the ankle, which corrects the valgus deformity of the limb and knee. On the rare occasion that these corrective actions do not reduce a chronic lateral patella subluxation or dislocation, a lateral release is performed.

ALIGNMENT AND 3- AND 6-YEAR SURVIVORSHIP OF KINEMATICALLY ALIGNED TOTAL KNEE ARTHROPLASTY

Kinematically aligned TKA can restore the native alignment of the limb, knee, and joint line, provide an acceptable angle in patients with severe varus and valgus deformities with flexion contracture, and rarely requires release of the collateral,

[†]References 3, 13, 15, 19, 27, and 28.

FIG 160.11 This composite shows the preoperative radiographs of a post-traumatic knee with a severe varus deformity, flexion contracture, and chronic posterior cruciate ligament insufficiency; an intraoperative photograph of the varus deformity; and a postoperative computer tomographic scanogram of the limb and axial views of the femoral and tibial components. The kinematically aligned TKA restored the native alignment and laxities of the knee without a release of the medial collateral ligament. This TKA was performed with posterior cruciate ligament–substituting implants because of the torn posterior cruciate ligament. The tibial component is 6° externally rotated on the femoral component, which is acceptable *(green lines)*.

retinacular, or posterior cruciate ligaments (see Figs. 160.11 and 160.12). A multicenter comparison of three case series showed that mechanically aligned TKAs performed with patient-specific and conventional instrumentation had more varus limb and knee outliers than kinematically aligned TKAs performed with patient-specific instrumentation.[29] A Level 1 randomized trial showed that the hip-knee-ankle angle (0.3 degrees difference; $P = .693$) and anatomic angle of the knee (0.8 degrees difference; $P = .131$) were similar for kinematically and mechanically aligned groups. In the kinematically aligned group, the angle of the femoral component was natively aligned 2.4 degrees more valgus ($P < .0001$) and the angle of the tibial component was natively aligned 2.3 degrees more varus ($P < .0001$) than the mechanically aligned group.[9]

Several studies suggest that the 2-degree average varus alignment (range 7 degrees varus to 7 degrees valgus) of the kinematically aligned tibial component relative to the mechanical axis of the tibia in the coronal plane should not have an adverse

FIG 160.12 Composite shows the preoperative weight-bearing *(white arrow)* radiographs of the knee with severe valgus deformity, intraoperative photograph of the severe valgus deformity and flexion contracture, and postoperative computer tomographic scanogram of the limb and axial views of the femoral and tibial components. The kinematically aligned TKA restored the native alignment of the limb *(vertical green line)*, set the rotation of the tibial component 3° externally rotated on the femur *(transverse green lines)*, and restored the laxities of the native knee without a release of the lateral collateral ligament in this patient with an intact posterior cruciate ligament.

effect on implant survivorship. A study of mechanically aligned TKAs reported that a 3-degree varus average alignment (range >7 degrees varus to 5 degrees valgus) was associated with a high implant survivorship of 96% at 10 years.[24] Two case series, each consisting of more than 200 kinematically aligned TKAs, reported a low incidence of catastrophic failure regardless of the alignment category at 3- and 6-year follow-up and high restoration of function as measured by the self-reported Oxford Knee Score. At 3 and 6 years, 75% and 80% of tibial components, 33% and 31% of knees, and 6% and 7% of limbs were categorized as varus outliers. These outliers were associated with a low 0% and 0.5% incidence of catastrophic failure of the femoral or tibial component and a high average Oxford Knee Score (48 best) of 42 and 43 points.[13,17] Another study opined that the reason for the good implant survivorship of kinematically aligned TKA is that 89% of kinematically aligned tibial components are aligned parallel within 0 ± 3 degrees relative to the floor in a weight-bearing film, which is more akin to how the

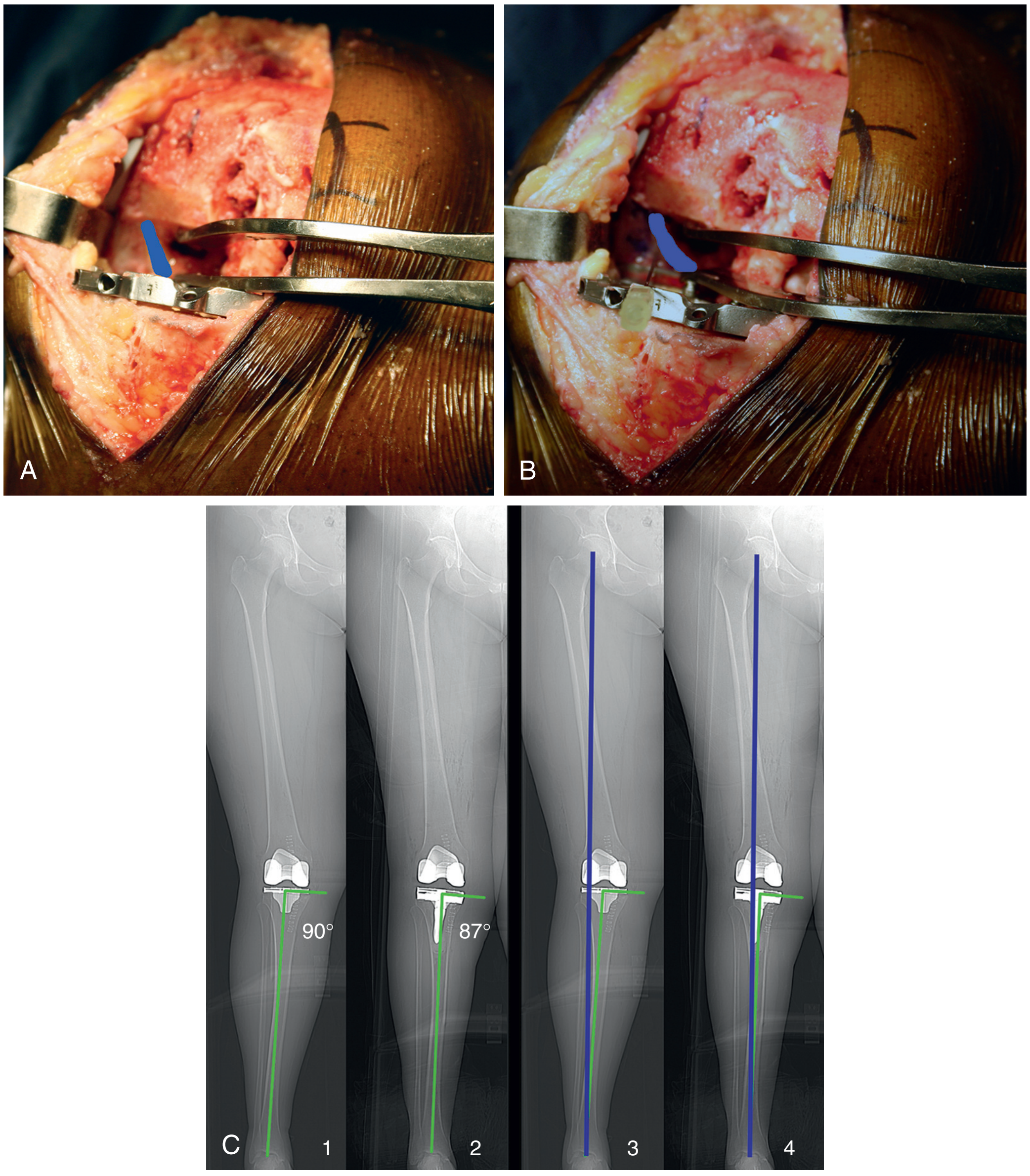

FIG 160.13 Composite shows the laminar spreader and the length of the gap *(oblique short blue lines)* in the lateral side of a right knee before (A) and after a 3 mm incremental lengthening of the lateral collateral ligament with use of the pie-crusting technique (B), and the use of the pie-crusting technique in another patient to correct the alignment of the knee and limb left too valgus at the time of primary kinematically aligned TKA (C). The tibial component in the primary surgery was originally set at 90° to the mechanical axis of the tibia (angle formed by *green lines*) *(1),* which left the leg too valgus *(3)*. The revision followed the step-wise algorithm for correcting the valgus deformity by adjusting the varus-valgus alignment of the tibial component and leaving the original femoral component alone (Fig. 160.10). At revision, the varus-valgus alignment of the tibial component was set at 87° to the mechanical axis of the tibia by lengthening the lateral collateral ligament 3 mm *(2),* and the insertion of a thicker liner moved the ankle 20 mm more medial, which realigned the limb to neutral *(vertical long blue lines) (4)*.

prosthesis is functionally loaded in mechanically aligned TKA with good survivorship.[20] Therefore, the concern that kinematic alignment places the components at a high risk for catastrophic failure and compromises function is allayed. This result should be of interest to surgeons who are committed to cutting the tibia perpendicular to the mechanical axis of the tibia.[17]

SUMMARY

Kinematically aligned TKA has gained interest because two randomized trials and a national multicenter study showed that patients treated with kinematic alignment reported significantly better pain relief, function, flexion, and a more normal feeling knee than mechanical alignment with similar implant survivorship at 2, 3, and 6 years.[4,8,17,18,26] A caliper measurement of the thicknesses of the distal and posterior femoral resections that equals the thicknesses of the condylar regions of the femoral component after compensating for cartilage wear and kerf provides quality assurance that the femoral component is kinematically aligned. Alignment references used to position the femoral component in mechanically aligned TKA, such as the femoral mechanical axis, intramedullary canal, transepicondylar axis, and anterior-posterior axis, are not of interest or of use when performing kinematically aligned TKA. Ensuring that the native alignment and laxities of the knee are closely restored to normal involves the following tasks:

1. Setting the internal-external rotation of the tibial component based on the major axis of the lateral tibial condyle or a kinematic tibial baseplate;
2. Extending the knee to 0 degrees of flexion and adjusting the varus-valgus angle and thickness of the tibial component until the varus-valgus laxity is negligible; and
3. Flexing the knee to 90 degrees and adjusting the anterior-posterior slope and thickness of the tibial component until the offset of the anterior tibia from the distal medial femoral condyle matches that of the knee at the time of exposure and the internal and external rotation of the tibia on the femur approximates 14 degrees.

Alignment references that are used to position the tibial component in mechanically aligned TKA, such as the tibial mechanical axis, intramedullary canal, posterior condylar axis, and tibial tubercle are not of interest or of use when performing kinematically aligned TKA.[‡] Aligning the femoral and tibial components kinematically, removing osteophytes, and retaining the native lengths of the medial collateral, lateral collateral, and posterior cruciate ligaments closely restore the native tibial-femoral articular surfaces, the native knee and limb alignment, and the native laxities of the knee.

[‡]References 3, 13, 15, 19, 27, and 28.

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