The Kinematic Alignment Technique for Total Knee Arthroplasty

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Key Points
- Kinematic alignment (KA) is a relatively new surgical technique for implanting total knee components.
- The vast majority of patients are eligible for a kinematic implantation, and this may be achieved with most primary implant designs.
- Kinematically aligning the femoral component is relatively easy and straightforward; following this first step, the kinematic tibial implant positioning is made reproducible by a combination of measured resection and ligament referencing techniques. As the surgical technique is not demanding and complex cases are rare, the KA technique is overall reliable.
- KA implantation results in high prosthetic joint function, in a large range of preoperative deformity, and whether the postoperative alignment of the tibial component, knee and limb is in the varus and valgus outlier range of mechanical alignment criteria.
- Due to an improvement in knee biomechanics, it is expected that component lifespan will also be improved. A prospective study of 222 successive unselected KATKAs has reported excellent implant survival at 10-year follow-up. Nevertheless, long-term outcomes of KA patients still need to be defined.
- In the event of severe constitutional limb deformity, kinematic component positioning may be adjusted in order to reduce the limb deformity and hopefully improve prosthetic biomechanics. This defines the restricted kinematic alignment concept.
- Development of new implant designs adapted to KA implantation needs to be undertaken.

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16.1 Introduction

16.1.1 What Is It? The Concept

The kinematic alignment technique (KA) for total knee arthroplasty (TKA) is a surgical technique recently developed that aims to anatomically position and kinematically align total knee

components [1]. The kinematic implantation aims to resurface the knee joint by removing a cartilage and bone thickness equivalent to the implant thickness and where the knee implants are aligned on the knee kinematic axes that dictate motion of the patella and tibia around the distal femoral epiphysis [2–4]. Similar to unicompartmental knee replacement, kinematically aligning total knee components restores the constitutional knee joint line orientation and the physiological knee laxity without the need for soft-tissue release [5] (Fig. 16.1).

16.1.2 Why Has This New Surgical Technique Been Developed? The Rationale

The KA technique for TKA has been developed following the observations that mechanically aligned (MA) TKAs are affected by residual complications that have not been solved by technology, and the rationale for the MA technique is being challenged.

MA-TKAs are affected by residual complications that have not been solved by technology [6–10], thus suggesting intrinsic technical limitations. The proportion of residual knee symptoms (e.g. pain, instability, effusion) and patient dissatisfaction after MA-TKA has been reported to be as high as 50% and 20%, respectively [6–10]. Interestingly, neither the multiple modern TKA designs nor the many technological assistive devices (e.g. computer assistance, robotics, personalized instrumentation) have solved the issues [6–10]. The mechanical alignment technique is a technically challenging [11–13], systematic technique of implantation [5] that generates non-physiological prosthetic knee anatomy [5, 11, 14], balance [11, 15] and biomechanics [16–18]. Aiming at a similar component implantation alignment goal, it does not recreate the high variability in knee anatomy [14, 19] and laxity [20] between individuals. This may be responsible for
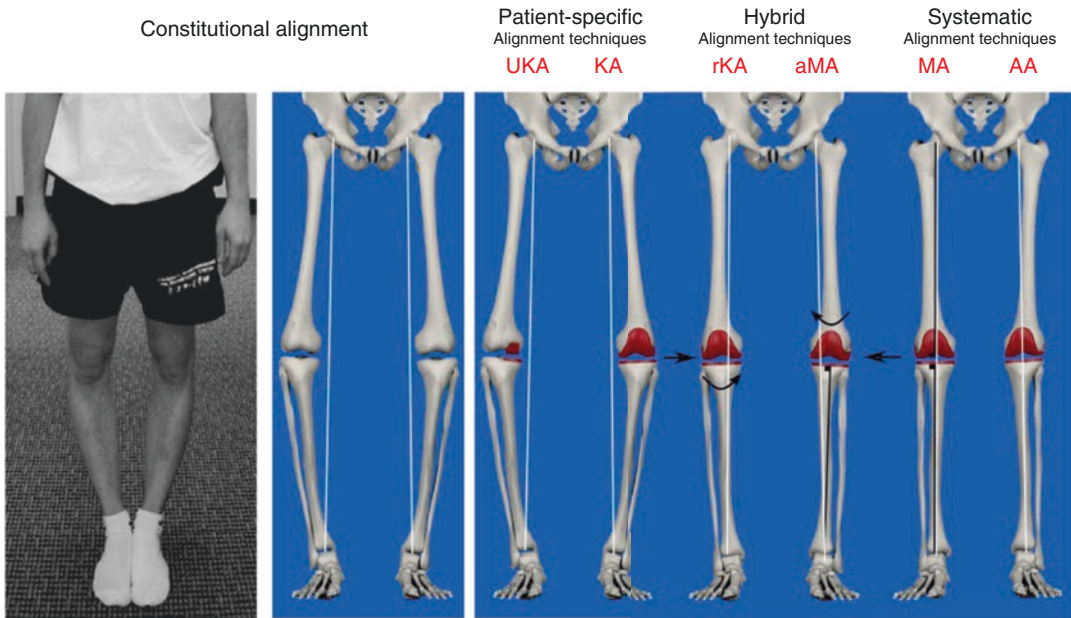

Fig. 16.1 The multiple philosophies for aligning knee components. Mechanical alignment (MA) and kinematic alignment (KA) are two different techniques for positioning knee components. MA and KA may have their component positioning adjusted in order to generate a more physiological (adjusted MA, aMA) or biomechanically sound (restricted KA, rKA) prosthetic knee. Only the unicompartmental knee replacement (UKA), KA and rKA are personalized techniques for implanting knee components

non-physiological knee ligament laxities and residual instability [10, 11, 15] and abnormal knee kinematics [13, 16, 17]. To illustrate these points, the MA technique was linked to:

1. Frequent prosthetic overstuffing of the distal lateral femoral condyle [11] which leads to abnormal stretching of the lateral retinaculum ligament during knee flexion.
2. Frequent, uncorrectable collateral ligament imbalance when performed with a measured resection technique (approximately 40% imbalance ≥2 mm) [11, 12] or gap-balancing (knee flexion gap tighter than physiological) [15] techniques.

The **rational of mechanically positioning knee implants is being challenged**:

– *The first pillar* of the MA technique is to align knee components systematically, perpendicular to femoral and tibial mechanical axes. In fact, a bulk of evidence now suggests that knee kinematics is dictated by three main axes (Fig. 16.2) [2], and the cylindrical (or transcondylar) axis is the one upon which the tibia effectively rotates around the femur from 10° to 120° of knee flexion [4].
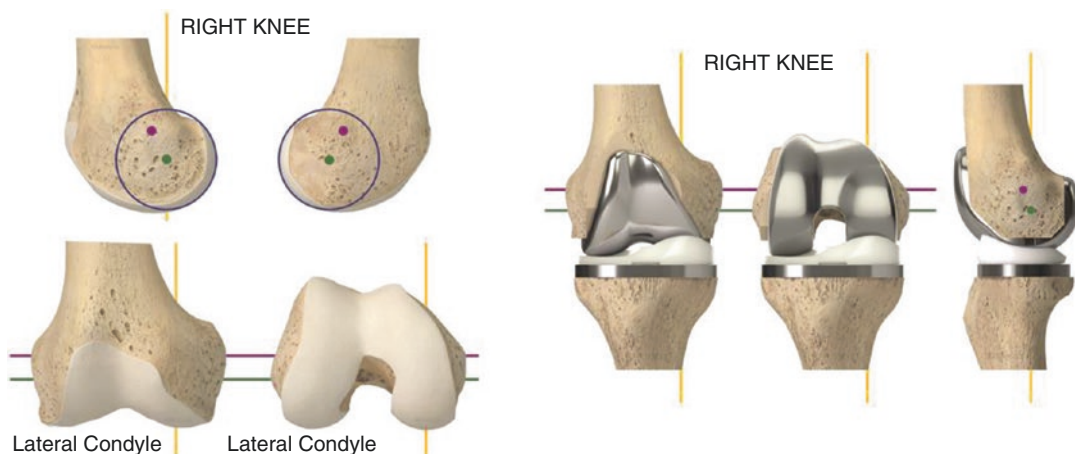
– *The second pillar* of the MA technique is the assumption that generating a neutrally aligned knee when standing creates a biomechanically friendly knee component environment that would persist even during gait. By reducing the prosthetic joint reaction force, this would optimise the lifespan of the components. In fact, many studies have now challenged this dogma, after having found that static standing limb alignment (hip knee ankle (HKA) angle) poorly predicts the risk of long-term MA-TKA failure [21, 22]. This may be due to the fact the HKA angle is a dynamic (or functional) value that changes when weight bearing [23] and walking [24] and that only partly predicts the knee adduction moment [24, 25] and the medial femoro-tibial joint reaction force [26].

– *The last pillar* of the MA technique is the assumption that generating rectangular and identical extension and flexion gaps would be clinically beneficial. However, some recent studies suggest that preserving the physiological ligament laxity difference between the medial and lateral compartments and between the flexion and extension spaces may in fact be clinically advantageous [27].

Fig. 16.2 Kinematically implanted knee components are aligned on the three main knee kinematics axes, which dictate physiological knee motion. This is achieved by anatomically positioning knee components or, in other words, by performing a true total knee resurfacing. Transcondylar or cylindrical axis (green); patellar axis (purple); tibial longitudinal axis (yellow)

16.1.3 What Are the Intended Benefits?

By aiming for a more physiological and more reproducible implantation, the KA technique aims to improve prosthetic knee function, patient satisfaction and component lifespan, compared to conventional techniques for knee replacement. The anatomic knee reconstruction has been shown to be clinically beneficial [28] by means of the generation of a close to physiological peri-prosthetic soft-tissue tension [29, 30] and prosthetic knee biomechanics [31–34]. Interestingly, the kinetic aspect of a KA-TKA may also be advantageous (reduced prosthetic joint reaction force) compared to MA [31, 33, 34]. Those functional and biomechanical advantages with KA would hopefully contribute to counter the raising burden of revision in patients who are having joint replacement younger, with higher demands and expectations, and a longer life expectancy [7, 8].

16.2 Planning a Kinematic Implantation

16.2.1 Which Patient Can Be Kinematically Implanted?

Primary replacements requiring revision knee implants to treat a deficient knee soft-tissue envelope (e.g. MCL stretching and severe valgus knee) or severe bone loss are not eligible for KA. This is due to the design of revision implants, where the stem-implant angle dictates the implant orientation (often 6° for femur and 0° for tibia).

There is currently no evidence that osteoarthritic knees that require a primary replacement with sliding components lead to the preclusion of a surgeon using KA. Out of 219 consecutive unselected KA-TKAs prospectively followed for 10 years, prosthetic knees resulting in varus or valgus limb alignment (>3°) performed similarly as the ones neutrally aligned knees. Only three aseptic revisions (1.6%) were observed and were related to technical error in component positioning [35]. Similarly, the fact that only 13

cases of patella instability were reported out of 3212 consecutive KA-TKAs indicates that the vast majority of patella-femoral joints and axial femoro-tibial rotations may be safely reproduced when kinematically implanting total knee components [36].

Nevertheless, it is likely that certain types of constitutional anatomy may be biomechanically inferior and thus clinically detrimental if reproduced (osteoarthritic knee types 2, 3 and 5; Table 16.1).

– The safe range for frontal kinematically positioned total knee components is yet to be determined [5]. This explains why some authors use KA unless the patient is an outlier, with excessive deviation from the average constitutional knee anatomy [37, 38]. In this event, those authors would adjust the kinematic components positioning, by slightly deviating from the native anatomy, in order to fit an arbitrarily defined, range of component positioning and limb alignment [37, 38]. This defines the concept of restricted kinematic alignment, best illustrated by the Montreal protocol (see Chap. 17) [37, 38]. The outlier constitutional knee/limb anatomies must not be confused with extra-articular deformities resulting from trauma (e.g. femoral diaphysis malunion), which are not physiological. These more often need to be corrected with an additional osteotomy at the time of TKA (one stage) or before (two stages) the TKA.

– Similarly, the safe range for axially kinematically positioned total knee components is unknown [5]. Kinematically implanting patients having an antecedent of patella instability (osteoarthritic knee type 5; Table 16.1) may seem unreasonable as reproducing a poor anatomy (e.g. excessive Q angle or trochlea groove-tibial tuberosity distance) may lead to failure. As stated above, with solely 13 cases of patella instability out of 3212 consecutive unselected KA-TKAs [36], the vast majority of patella-femoral joint anatomies and axial femoro-tibial rotations may, apparently, be safely reproduced.

Table 16.1 Table illustrating different types of knee that make a kinematic implantation simple, complex or not indicated

	Simple KA-TKA	Complex KA-TKA				No KA-TKA
Knee type	1	2	3	4	5	6
Definition	None of the criteria defining the types 2, 3, 4, 5, 6	>5° constitutional varus	>5° constitutional valgus	Severe bone loss	Antecedent of patella instability	Deficient soft-tissue envelope
Surgical planning	KA	KA **or** 'KA + realignment osteotomy' **or** rKA		KA (unless revision implant needed)	KA ±MPFL reconstruction ±lateral retinaculum release and VMO plasty ±extensor mechanism realignment	**Constrained implants needed, KA technique not indicated**

Knee types 2, 3, 4 and 5 represent situations of complexity that are important to preoperatively recognise for refining the planning of the kinematic implantation

16.2.2 Which Implant Design May Be Kinematically Implanted?

It is likely that the majority of traditional primary implant designs (symmetrical sliding designs) available on the market such as medial pivot and cruciate(s) retaining or substituting designs may be suitable for a kinematic implantation. As kinematic prosthetic implantation aims to restore close to physiological knee kinematics, implant designs that promote unconstrained, physiological femoro-tibial kinematics and that preserve or replicate cruciate ligament(s) function are probably the most sensible for use. For this reason, kinematic implantations have traditionally been reported with fixed bearing cruciate-retaining implant designs [35–37, 39–42]. Nevertheless, successful kinematic implantation with mobile bearing postero-stabilised implant design has also been reported [43]. After having used cruciate-retaining and postero-stabilised designs, the author (CR) is now performing kinematic implantation with a medial pivot TKA component design [44]. By offering anteroposterior stability (substitution of both cruciate ligaments and medial meniscus) and medial implant congruency (ball in socket), medial pivot TKA design may be clinically advantageous by providing improved knee stability and reduced linear polyethylene wear. There is no study having compared the value of the multiple implant designs when kinematically positioned. Further research is therefore needed.

Asymmetric components with built-in joint line obliquity (e.g. Journey™, Genesis™—Smith & Nephew), because of asymmetry in the thicknesses of their medial and lateral compartments, are specifically designed for mechanical implantation (thus creating the effect of an anatomical alignment - see Fig. 16.1) and are inappropriate for kinematic alignment.

16.2.3 Which Instrumentation to use?

Conventional gap-balancing techniques, serving to define the femoral axial rotation, are inappropriate for KA. This is because a kinematic femoral component is always implanted parallel to the posterior condylar line (neutral rotation) in order to be adequately aligned with the cylindrical (trans-condylar) axis. This is easily achieved with a posterior referencing resection guide.

KA can be performed manually [45, 46] or with the use of assistive technology [35, 37, 39–41, 43]. Successful implantations have been

reported using measured-resection manual instrumentation (Chap. 24) [45, 46], navigation systems (Chap. 26) [37, 43] and personalized cutting guide (Chap. 25) [35, 39–42]. A modified gap-balancing technique for performing the tibial cut is also being assessed [47].

Technological assistance (e.g. computer, robotics or PSI) is probably most of interest with the *restricted KA concept* [5, 37, 38, 48], by informing the surgeon about the patient's knee

Fig. 16.3 The calliper is the key tool for successful KA implantation. Distal and posterior femoral cuts and the tibial cut must always be measured. The resection thicknesses should match those of the components, after compensating for cartilage and bone wear and the 1 mm kerf from the saw cut

anatomy and the ability to precisely execute anatomy adjustment when needed. The restricted KA concept consists of restricting the use of the pure kinematic technique only for individual with HKA deviation above 3° and/or distal femoral/proximal tibia joint line obliquity higher than 5° (Montreal protocol, see Chap. 17) [38]. Outlier patients will have their component positioning adjusted by slightly deviating from their constitutional knee anatomy (adjusted kinematic implant orientation). When performing a pure kinematic implantation (no adjustment), it remains to be seen whether technological assistance is of any clinical advantage as the kinematic components positioned with manual instrumentation have been shown to be highly reliable in terms of reproducibility of implant positioning [46, 49, 50] and clinical outcomes [45, 46]. This is the result of using reliable intra-articular anatomical landmarks to set the level and orientation of the bone cuts, knowing the expected bone resection thicknesses, controlling their quality with a calliper (measured resection technique; Fig. 16.3) and by assessing the collateral ligaments tension with spacer block and/or trial implants (ligament referencing technique) and easily refining the cuts with specific user-friendly recut guides (Fig. 16.4, and see Chap. 24).
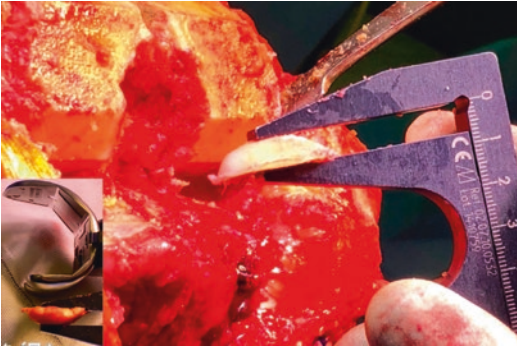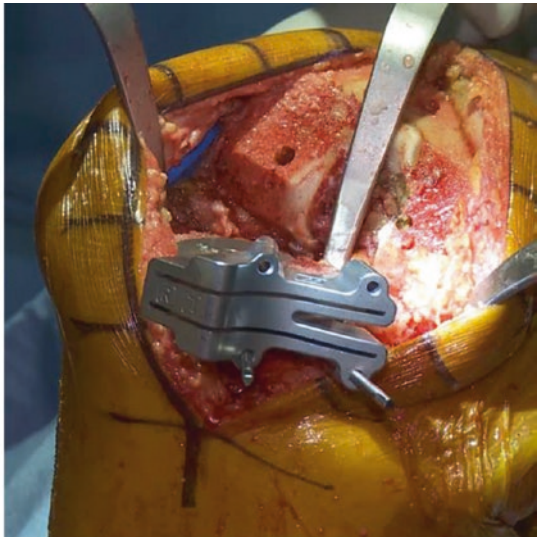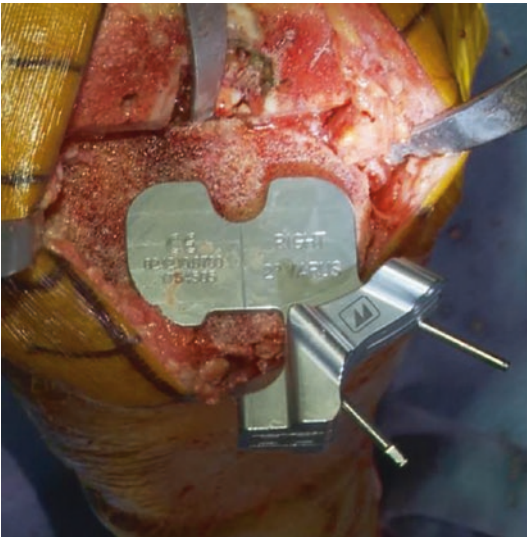

Fig. 16.4 Recently launched specific KA instrumentation™ (Medacta, Switzerland). It helps to compensate for cartilage loss on the femoral side as well as easing the refinement of the tibial cut through the various recut guides (additional tibia varus or valgus or slope). This figure illustrates the varus/valgus recut guide

16.2.4 Resurface the Patella or Not?

There is unfortunately no evidence to help with this choice. As MA and KA implantations significantly differ from each other, the evidence accumulated for the former technique can't be translated to the latter one.

MA frequently generates lateral femoral condyle prosthetic overstuffing that affects the patella balance (lateral retinaculum stretching) and biomechanics (lateral patella tilt/shift and increased lateral facet joint reaction force) when flexing the knee [11] and is sometimes responsible for MA-TKA failures [35, 36, 42]. In contrast, this significant alteration of the lateral femoral condyle anatomy does not occur when knee components are KA [11, 51, 52] and probably explains the more physiological patella biomechanics [33, 34] and the rare anterior knee pain [42, 53] and patella instability [35, 36] after KA-TKA. The improved patella environment after KA-TKA, relative to MA-TKA, may have a protective effect on it, whether it has been replaced or not. This would hopefully be clinically beneficial by reducing the risk of patella-femoral joint-related complications [35, 36, 42].

16.2.5 Recognising a Complex Case for KA Implantation

As KA and MA implantation significantly differ, both techniques are complex in different situations. A classification of the most frequent conditions that would make KA-TKA complex is illustrated in Table 16.1.

In contrast to MA, the frontal limb deformity is generally not a source of technical complexity with the KA technique [11, 12, 29, 30]. This is because the anatomical joint reconstruction given by KA reliably restores the physiological knee soft-tissue balance whatever the constitutional limb alignment of the patient [11, 12, 29, 30]. Therefore, constitutional frontal limb deformity does not add surgical complexity unless considered excessive and needing attenuation (restricted KA) or correction (additional osteotomy before or at the time of the KA-TKA). While arbitrarily defined by some authors [37, 38], the optimal deformity threshold is yet to be scientifically defined.

Complex KA-TKA is frequently found in situations of substantial articular surface bone loss. The assessment of the medial (valgus stress) and lateral (varus stress) femoro-tibial spaces before any cuts (Fig. 16.5) gives an idea of the
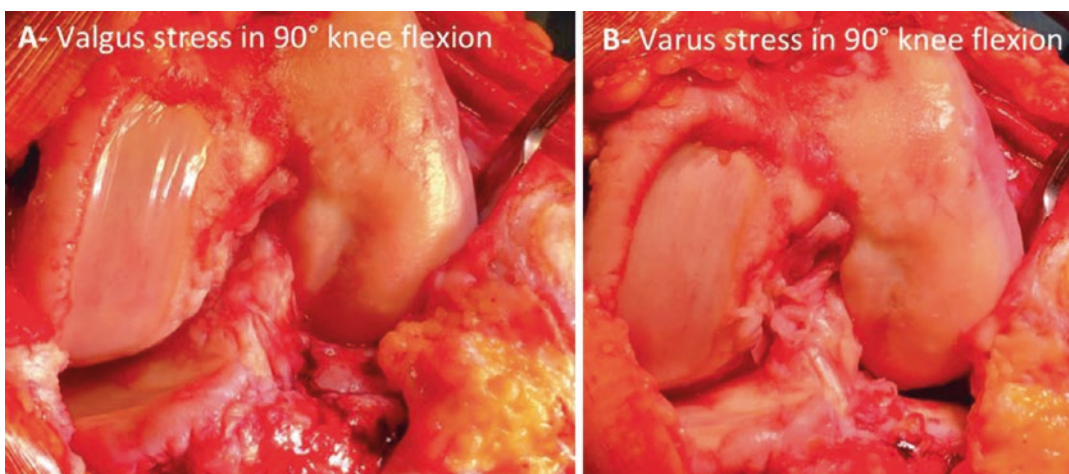

Fig. 16.5 Before performing any bone cuts, it is important to estimate the physiological knee laxity and amount of bone loss by doing varus (**b**, **d**) and valgus (**a**, **c**) stress tests in 90° (**a**, **b**) and 10° knee flexion and at full extension (**c**, **d**). In this case, there is a 3 mm to 4 mm physiological lateral laxity in flexion (**b**) but none at full extension (**d**) when doing a varus stress test. In contrast, there is excessive medial laxity when doing a valgus stress test, around 5 mm in flexion (**a**) and 10 mm in extension (**c**), which suggests significant medial compartment bone loss
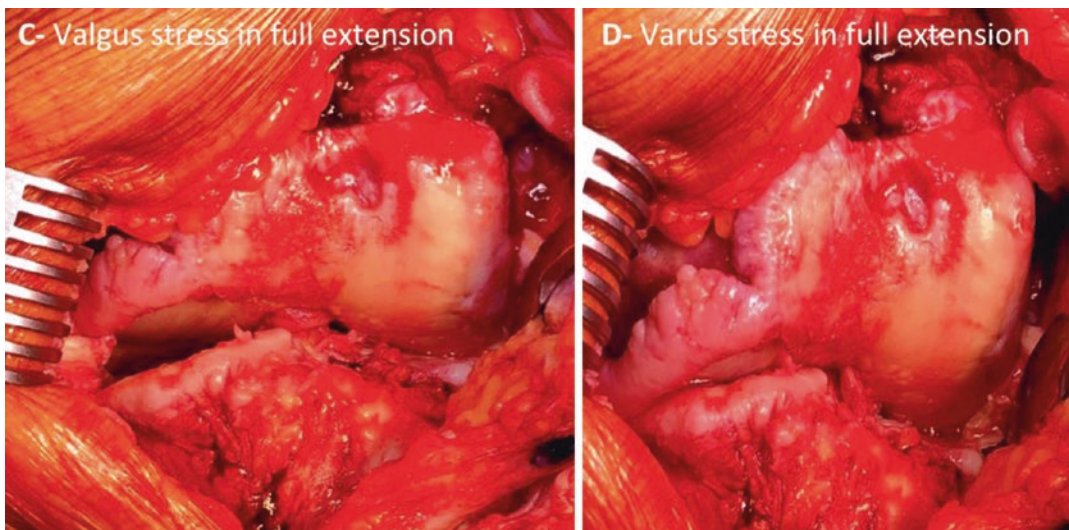
Fig. 16.5 (continued)

physiological femoro-tibial laxity and amount of bone loss and helps with planning the bone resection thickness. Then, by respecting the stepwise approach of a KA technique, with economic bone cuts followed by calliper-based quality control and potential recuts, KA in cases of substantial articular surface bone loss is usually relatively straightforward.

Patients with patella maltracking and/or a previous history of patella-femoral instability may need additional surgical correction (e.g. MPFL reconstruction, tibial tuberosity mobilisation) at the time of KA-TKA in order to optimise the patella tracking. Also, because the lateral retinaculum is often retracted in these cases, performing a lateral para-patellar arthrotomy, in addition to a plasty of the lateral retinaculum (Keblish style), may be advisable.

16.3 Key-Points for Performing a Kinematic Implantation

This section will only highlight key points of the KA technique. More details are provided in Chap. 24. The KA surgical technique significantly differs from the conventional MA tech-

nique. The only similarity between the techniques is in the execution and goal for sagittal femoral component positioning (Table 16.2) [5, 54]. The knee bony landmarks traditionally used for MA implantation are of little use when positioning implants using the KA technique [55, 56]. This is because the KA technique pays attention to intra-articular anatomical reference landmarks and strives to recreate the constitutional knee joint line orientation and knee laxity. In contrast, the MA technique focuses primarily of extra-articular long-bone mechanical axes and aims for mechanical component positioning [5, 54].

The KA technique follows a step-wise execution with the main steps being listed in Fig. 16.6. The KA implantation is traditionally a measured resection, femur first technique [45]. There are a few helpful tricks:

- First, *always estimate the individual physiological knee laxity and amount of bone loss* before performing any bone cuts, by varus/valgus stressing the knee throughout the knee range of motion (Fig. 16.5).
- Second, *always check the quality of the bone resection with a calliper* (Fig. 16.3). The expected thickness of the bone cut is easily

Table 16.2 Kinematic alignment (KA) and mechanical (MA) alignment are two different techniques for implanting knee components that only have in common the sagittal positioning of the femoral component

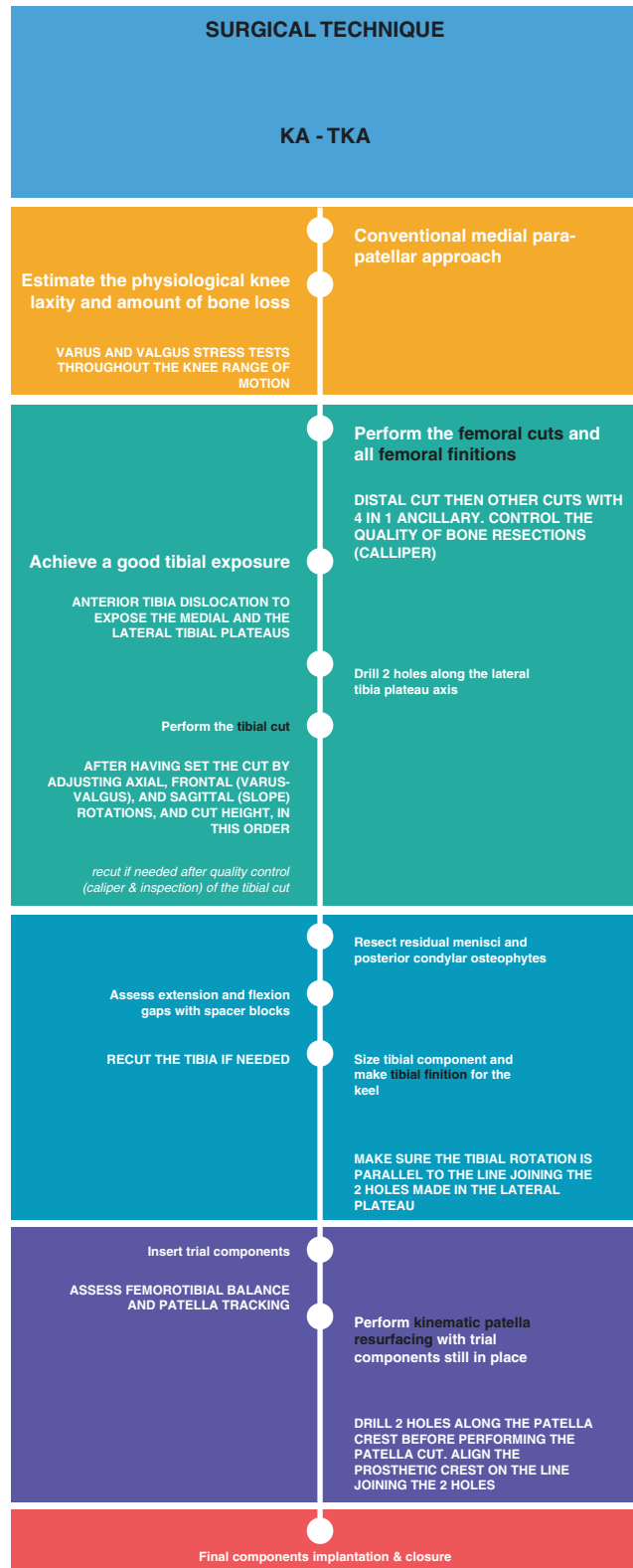|		KA technique	MA technique
Femoral component positioning	Flexion	Follows distal femoral bowing	Follows distal femoral bowing
	Varus-valgus	Parallel to the distal **femoral joint line** (considering articular surface wear)	Systematic and perpendicular to the femoral **mechanical axis**
	Rotation	Parallel to the **posterior condylar line Always measured resection and posterior referencing** techniques for a compromise done only on the trochlear offset	**External rotation** relative to the posterior condylar line. **Measured resection or gap-balancing** techniques. **Posterior or anterior referencing** techniques for a compromise done either on the flexion gap or on the trochlear offset, respectively
	Medio-lateral	Centred on the notch	**Slightly lateralised**
Tibial component positioning	Varus-valgus	Parallel to the proximal **tibial joint line** (considering the wear)	Systematic and perpendicular to the tibial **mechanical axis**
	Slope	Parallel to the **medial plateau slope**	**Systematic** and varies between 2° and 7° relative to the sagittal tibia mechanical axis
	Rotation	Parallel to **lateral plateau long-axis**	Towards the medial third of the **anterior tibial tuberosity**
Soft-tissue release	Femoro-tibial joint	**None**—close or physiological knee laxity automatically restored after bone cuts	**Frequent** for creating identical rectangular flexion and extension gaps
	Lateral retinaculum	**Rarely**—only in case of preoperative abnormal patella tracking with retracted lateral retinaculum ligament	**Often** performed to palliate the frequent prosthetic overstuffing of the lateral femoral condyle

calculated by deducting 1 mm from the implant thickness for the saw blade (kerf) thickness and by estimating the amount of articular surface wear. The cartilage thickness is frequently approximately 2 mm on the distal and posterior parts of the femoral condyles [57].

- Last, unless using technological assistance, *perform an economical tibial cut on the worn side* (Fig. 16.7) as the amount of bone loss is difficult to estimate precisely and it is easy to secondarily refine the tibia cut by using user-friendly KA-dedicated recut guides (Figs. 16.4 and 16.7).

If you face a femoro-tibial soft-tissue imbalance (tightness and/or excessive laxity) and the integrity of the knee soft-tissue envelope is still respected (no MCL or popliteal section), this is often because the tibial cut is improper. This is because performing a kinematic femoral component implantation is relatively straightforward and highly reproducible [49]. The solution is therefore to perform bone recuts by using specific recut guides that easily enable additional degrees of varus/valgus/slope to be made or an additional two millimetres of tibia to be cut. In summary, the kinematic tibial implant positioning is made reproducible by a combination of measured resection and ligament referencing techniques. The decision tree for solving imbalance while performing a kinematic implantation is illustrated in Fig. 16.8.

Fig. 16.6 The kinematic alignment technique for implanting total knee components follows a step-wise process that helps at making the implantation reliable
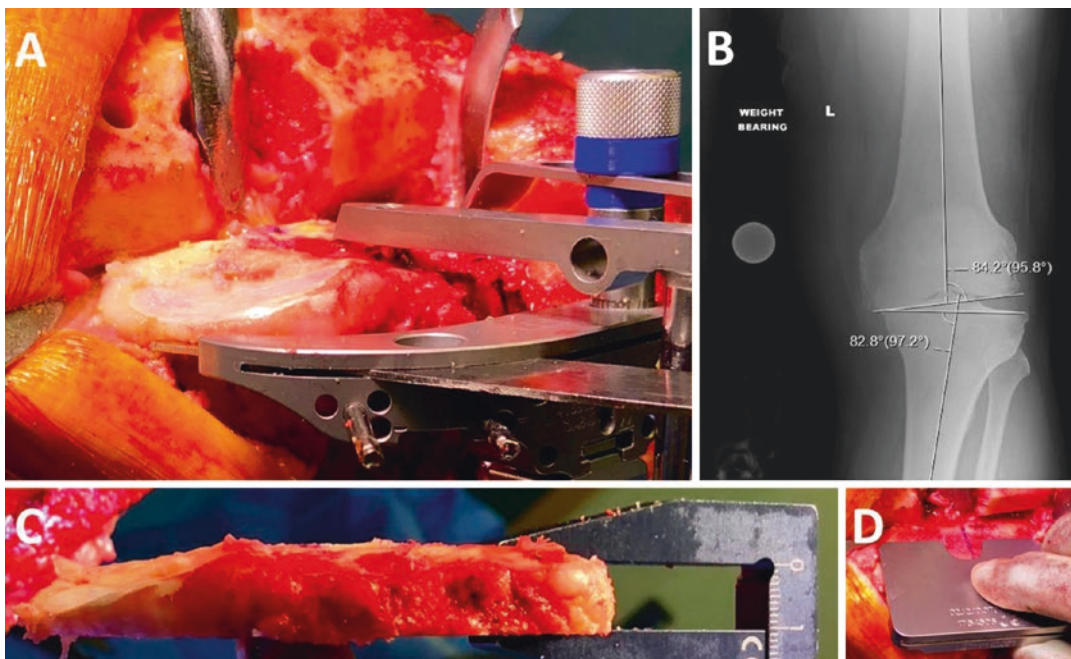

SURGICAL TECHNIQUE

KA - TKA

Estimate the physiological knee laxity and amount of bone loss

VARUS AND VALGUS STRESS TESTS THROUGHOUT THE KNEE RANGE OF MOTION

Conventional medial para-patellar approach

Achieve a good tibial exposure

ANTERIOR TIBIA DISLOCATION TO EXPOSE THE MEDIAL AND THE LATERAL TIBIAL PLATEAUS

Perform the femoral cuts and all femoral finitions

DISTAL CUT THEN OTHER CUTS WITH 4 IN 1 ANCILLARY. CONTROL THE QUALITY OF BONE RESECTIONS (CALLIPER)

Drill 2 holes along the lateral tibia plateau axis

Perform the tibial cut

AFTER HAVING SET THE CUT BY ADJUSTING AXIAL, FRONTAL (VARUS-VALGUS), AND SAGITTAL (SLOPE) ROTATIONS, AND CUT HEIGHT, IN THIS ORDER

recut if needed after quality control (caliper & inspection) of the tibial cut

Resect residual menisci and posterior condylar osteophytes

Assess extension and flexion gaps with spacer blocks

RECUT THE TIBIA IF NEEDED

Size tibial component and make tibial finition for the keel

MAKE SURE THE TIBIAL ROTATION IS PARALLEL TO THE LINE JOINING THE 2 HOLES MADE IN THE LATERAL PLATEAU

Insert trial components

ASSESS FEMOROTIBIAL BALANCE AND PATELLA TRACKING

Perform kinematic patella resurfacing **with trial components still in place**

DRILL 2 HOLES ALONG THE PATELLA CREST BEFORE PERFORMING THE PATELLA CUT. ALIGN THE PROSTHETIC CREST ON THE LINE JOINING THE 2 HOLES

Final components implantation & closure

Fig. 16.7 Performing a conservative tibial bone resection on the worn medial side (**a**, **c**) is recommended as it is not easy to precisely estimate the amount of bone loss (**a**, **b**). If the knee feels tight when assessing the flexion and extension gaps (spacer block), refinement of the tibial cut will be easily executed with the use of specific recut guides (**d**)

DECISION-TREE FOR BALANCING A CALIPERED KINEMATICALLY ALIGNED MEDACTA **GMK SPHERE CS** TKA					
Tight in Flexion & Extension	Tight in Flexion Well-Balanced in Extension	Tight in Extension Well-Balanced in Flexion	Well-Balanced in Extension and Loose in Flexion	Tight Medial & Loose Lateral in Extension	Tight Lateral and Loose Medial in Extension
Recut tibia and remove 1-2 mm more bone.	Confirm complete resection of the PCL. Increase posterior slope until natural A-P offset is restored at 90° of flexion.	Remove posterior osteophytes. Strip posterior capsule. Insert trial components & gently manipulate knee into extension.	Add thicker insert and recheck knee extends fully. If still loose in flexion, then reduce slope or resect 1-2 mm bone from distal femur and add thicker **GMK Sphere CS** insert.	Remove medial osteophytes. Reassess. Recut tibia in 1-2° more varus. Insert 1 mm thicker insert.	Remove lateral osteophytes. Reassess. Recut tibia in 1-2° more valgus. Insert 1 mm thicker insert.

Fig. 16.8 Decision tree for balancing a kinematically aligned TKA

16.4 Current Evidence

The KA technique has been developed for trying to reduce the high proportions of dissatisfaction [6] and residual complications [7, 8, 10] that traditionally affect MA-TKA and are probably as a result of non-physiological (neglecting of unique individual knee anatomy and laxity) [5, 11, 14, 31, 33, 34] and unreliable (high rate of uncorrectable collateral ligament imbalance) [11, 12] implantation. Studies having assessed the value of KA-TKA have flourished over the last years, and the promises seem to have been met.

The KA technique generates high prosthetic knee function and a more natural feeling. Seven studies have compared KA and MA patients at short term (1–2 years), including five randomised controlled trials [39–42, 58] and two matched case-control study [32, 43]. All have reported better functional scores for KA patients, while this was statistically significant for only five studies [32, 41–43, 58]. In addition, a national multicentre survey in the USA found KA patients to be three times more likely to report their knee to feel "normal" [6]. Faster recovery for KA patients [40, 59], reduced risk of anterior knee pain [42, 53] and similar failure rates [39–43, 53, 58] were other interesting findings from those comparative studies. Three meta-analyses [28, 60, 61] concluded the superiority of the KA technique in terms of prosthetic function and recovery time, with a similar low failure rate. High functional scores have been shown to persist 10 years after implantation, with no difference between different groups of limb alignment (varus >3°, neutral, valgus >3°) [35]. The faster recovery of KA patients could be the consequence of a more physiological and soft-tissue-friendly prosthetic knee implantation. This superiority is even more emphasised when the excellent clinical outcomes for KA patients were achieved despite the use of recently recalled Otismed™ cutting guides [39–42, 53] and by surgeons likely in their learning curve for the KA technique. In contrast, MA implantations, which were often found to be inferior to KA implantation, were performed by surgeons familiar with the technique and sometimes using navigation assistance [39, 43, 58].

With short-term data, KA prostheses rarely failed. The early complication rates (initial 1–2 years after implantation) were reported to be similar between KA and MA patients [39–43, 53, 58]. The 10-year aseptic revision rate has been reported at 1.6% with 1 tibial component loosening and 2 patella recurrent instabilities out of 219 consecutive unselected KA-TKAs [35]. There were no differences between varus, neutral and valgus groups of limb alignment [35]. Also, only 13 cases of patella instability were reported out of 3212 consecutive kinematically implanted prosthetic knee patients during a 9-year period [36]. KA implantation, therefore, results in high implant survival at 10 years regardless of the level of preoperative deformity and whether the postoperative alignment of the tibial component, knee and limb are varus and valgus outlier ranges according to MA criteria.

The KA technique is reliable as it accurately kinematically positions the knee components [46, 49, 50]. Studies have demonstrated that KA components with manual instrumentation is highly reproducible for both femoral [46, 49] and tibial [46, 50] components. Also, the KA technique has been shown to properly restore physiological knee laxity [29, 30].

The KA technique is more physiological as it is generating close to native biomechanics. Many studies have shown that the femoro-tibial [31, 32, 62] and patellofemoral [33, 34] KA prosthetic kinematics and kinetics (or biomechanics) more closely resemble those of the native knee, when compared to mechanically aligned TKA. Interestingly, it seems that kinematic implantation may also be kinetically more advantageous than mechanical implantation by better aligning the knee joint line parallel to the ground in situations of weight bearing [48, 63], leading to reduced deleterious shear stress on the bearing surfaces and component fixation interface. KA alignment also reduces the joint reaction forces at the lateral patella-femoral facet [33, 34] and through the medial femoro-tibial compartment [31]. The improved patellofemoral kinetics [33, 34] may be explained by the prosthetic trochlea anatomy in the kinematically positioned femoral component being closer to the native trochlea groove alignment [52, 64]. The improved tibio-femoral kinetics [31] may be explained by the more physiological gait pattern after KA implantation that results in a lower knee adduction lever arm and, subsequently, a reduced knee adduction

moment, despite the fact that lower limbs were slightly more varus [31]. This is not surprising when one realises that the frontal limb alignment (HKA angle) is a dynamic value [23, 24] that has been shown to poorly predict the knee adduction moment [24, 25] and the medial femoro-tibial joint reaction force [26]. The likely biomechanical advantage conferred to KA prosthesis may explain the very low rate of component failure that has been observed after KA [35].

16.5 Specific Component Designs for Kinematic Implantation?

Kinematically positioning contemporary knee components enables the restoration of the femoro-tibial joint line 3D orientation [46, 49], but it fails to accurately reproduce the individual trochlea anatomy [51, 52, 64]. This poor trochlea reconstruction is related to the fact that kinematic

positioning of monoblock femoral components focuses on the reconstruction of the femoro-tibial joint line, with no possibility to fine-tune the prosthetic groove orientation. While this poor prosthetic trochlea anatomical reconstruction has not been responsible for catastrophic failure [5, 35, 36], it may nonetheless hinder optimal clinical outcomes of KA prosthetic knee. Some trochlea anatomy variations may therefore benefit from a more personalized reconstruction.

The native trochlea anatomy has been shown to be highly variable between people [3, 52] and poorly predicted by the frontal limb/knee anatomical parameters [65]. Therefore, potential solutions to a more personalized trochlea reconstruction are threefold:

1. New modular femoral component designs offer the possibility to intraoperatively fine-tune the groove orientation/radius and trochlea stuffing (Fig. 16.9).
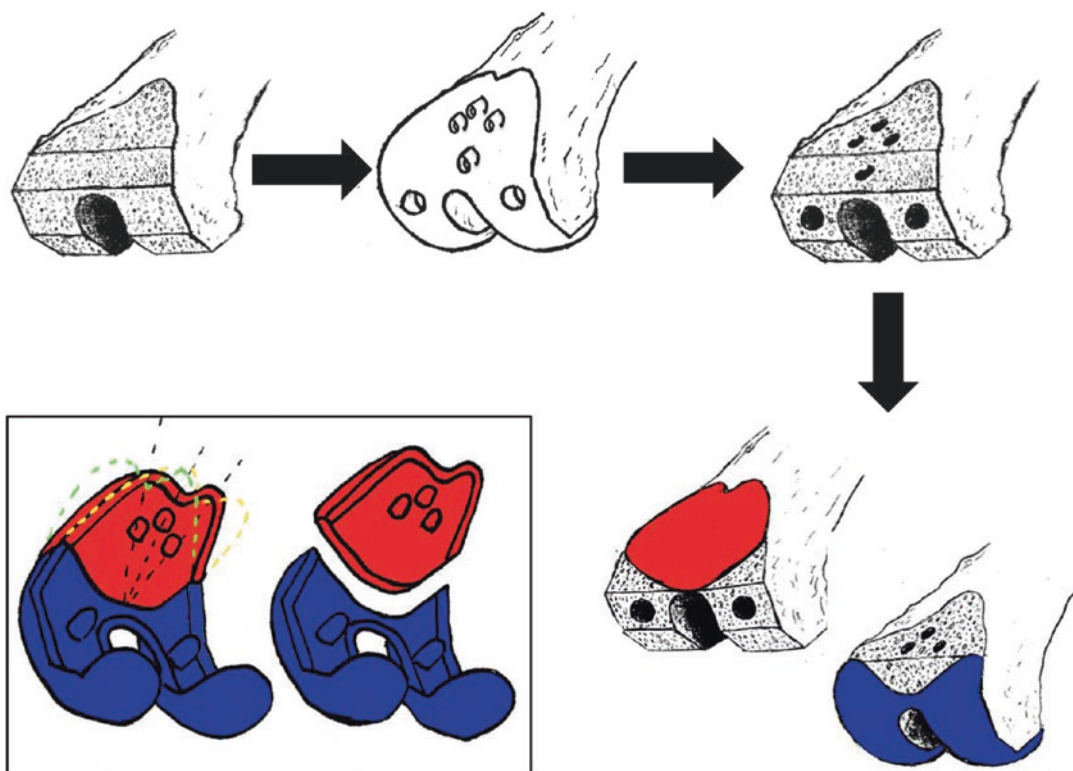

Fig. 16.9 A modular total femoral component may be one solution for restoring the individual femoro-tibial and patellofemoral joints anatomy and hopefully make clinical outcomes of KA patients even better. The surgeon would be offered the intraoperative ability to fine-tune the trochlea reconstruction (stuffing and groove orientation) and/or patella tracking by selecting through a wide range of modular trochlea designs that differ by their stuffing and groove orientation

2. Already existing custom femoral component (Origin™—Symbios, Yverdon-les-Bains, Switzerland—Fig. 16.10, Chap. 22).
3. New monoblock femoral component designs displaying various trochlea anatomies. The cost-effectiveness of the last two options may be questioned considering the current economic trend.

16.6 Conclusion

KA-TKA is a surgical technique that may help better reproduce physiological knee function without the need for soft-tissue release. The vast majority of osteoarthritic patients are eligible for a KA-TKA. Because the surgical technique is not demanding and complex cases are rare,
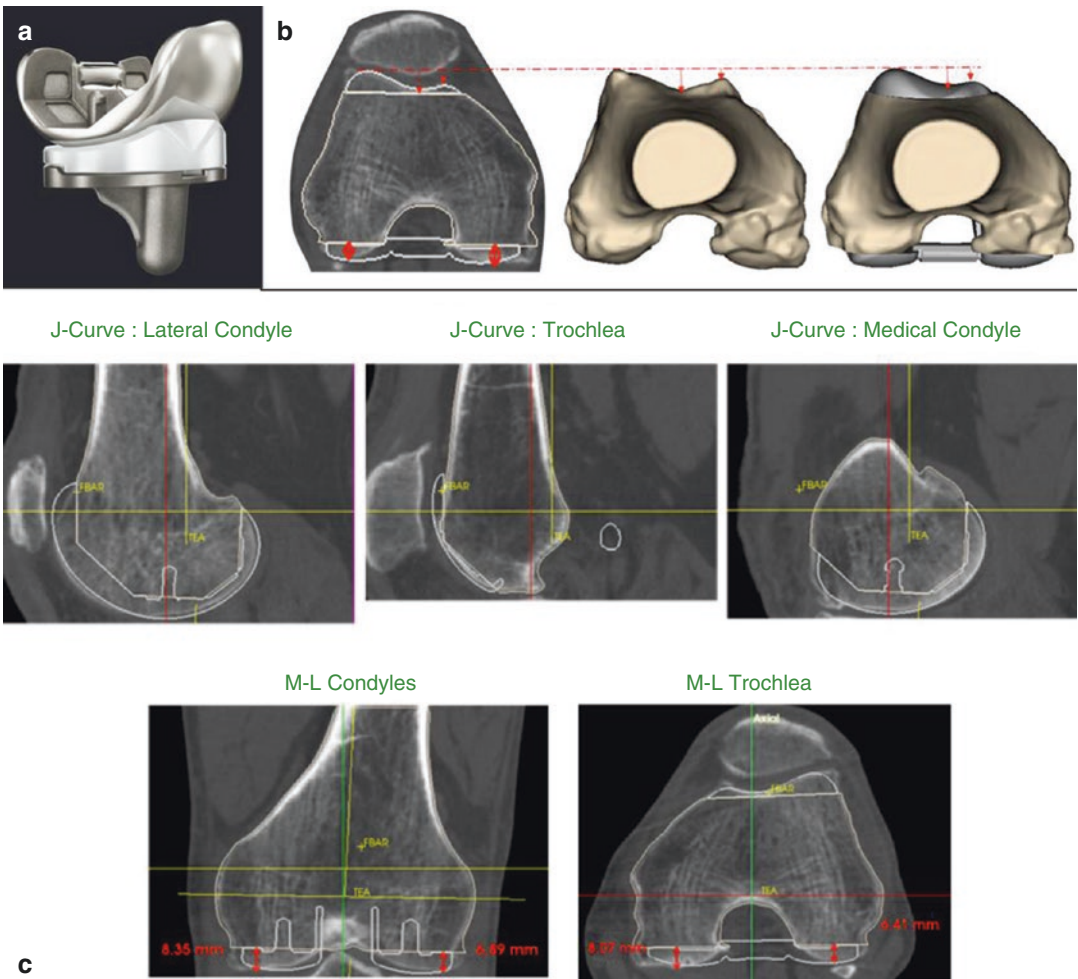
Fig. 16.10 The custom Origin™ total femoral component (Symbios, Yverdon-les-Bains, Switzerland) may be one solution for restoring the individual femoro-tibial and patellofemoral joints anatomy and hopefully make clinical outcomes of KA patients even better. The Origin™ (**a**) enables restoration of the individual trochlea (**b**) and femoro-tibial (**c**) anatomy

KA is reliable for most patients. KA implantation results in favourable implant survival and function at 10 years in a wide range of preoperative anatomies. Because the whole knee biomechanic environment is improved, it is hoped that component lifespan will also be improved. In the event of severe constitutional limb deformity, the kinematic component positioning may need to be adjusted in order to better suit the actual prosthetic fixation and bearing limitations; this defines the restricted KA concept. Long-term outcomes of KA patients still need to be defined. New TKA component designs that better match patients' knee anatomy and help replicate native knee kinematics may need consideration.

16.7   Case Illustration

A 66-year-old patient presented with painful, bilateral, severely degenerated knees. In the left knee, the patient had a correctable 10° to 15° varus deformity and a varus trust when walking. The knee range of motion was normal.

On plain radiographs (Fig. 16.11), there was bilateral, medial femoro-tibial bone-on-bone osteoarthritis. The left knee had a severe varus deformity with frontal femoro-tibial subluxation and some medial bone loss making the kinematic implantation slightly more complex than usual (knee type 5—Table 16.1).

Before performing any bone cuts on the left knee, the medial and lateral femoro-tibial laxities were assessed (Fig. 16.5), and an abnormal severe medial laxity was observed in full extension (Fig. 16.5b).

As shown in Fig. 16.12, the remaining cartilage thicknesses were assessed with a scalpel on the distal (Fig. 16.12a, b) and posterior (Fig. 16.12c, d) parts of each femoral condyle and on the lateral tibial plateau (Fig. 16.12e). There was no cartilage left on the distal medial condyle (Fig. 16.12a) and medial plateau and approximately 1 mm of cartilage loss on the posterior part of the medial condyle (Fig. 16.12c). 2 mm and 1 mm were then compensated for medially when performing the distal and posterior femoral cuts, respectively. Distal and posterior cuts were measured with a calliper and were within 0.5 mm of the plan.
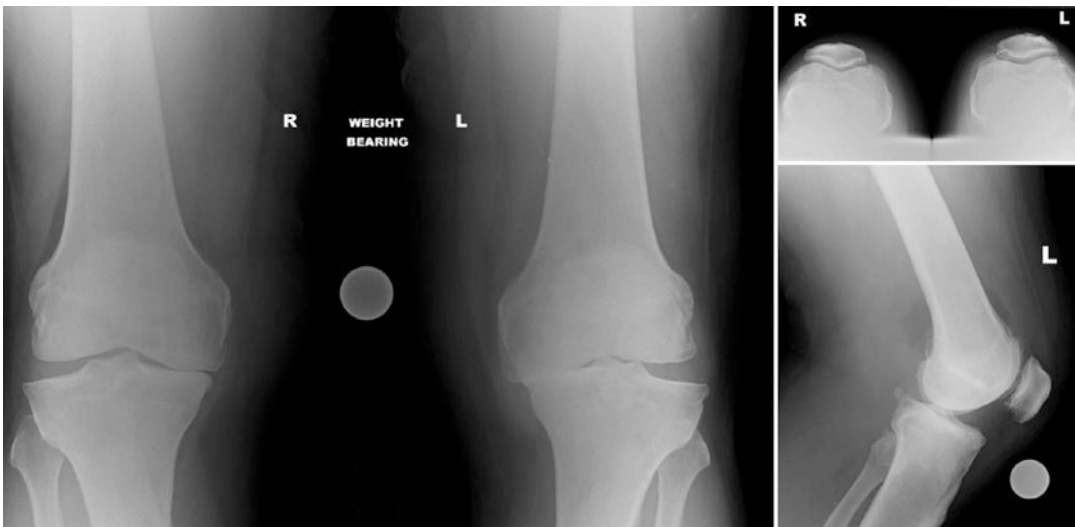

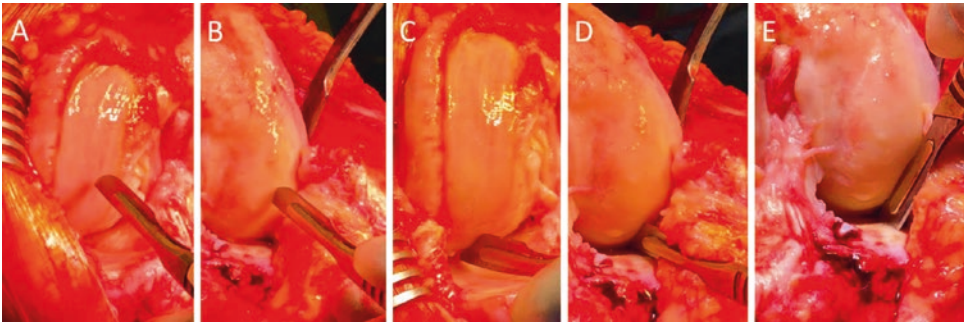**Fig. 16.11**   Pre-operative knee radiographs

Fig. 16.12 Intra-operative estimation of cartilage thickness on the distal (**a**) and posterior (**c**) parts of the medial femoral condyle, the distal (**b**) and posterior (**d**) parts of the lateral femoral condyle, and the lateral tibia plateau (**e**)
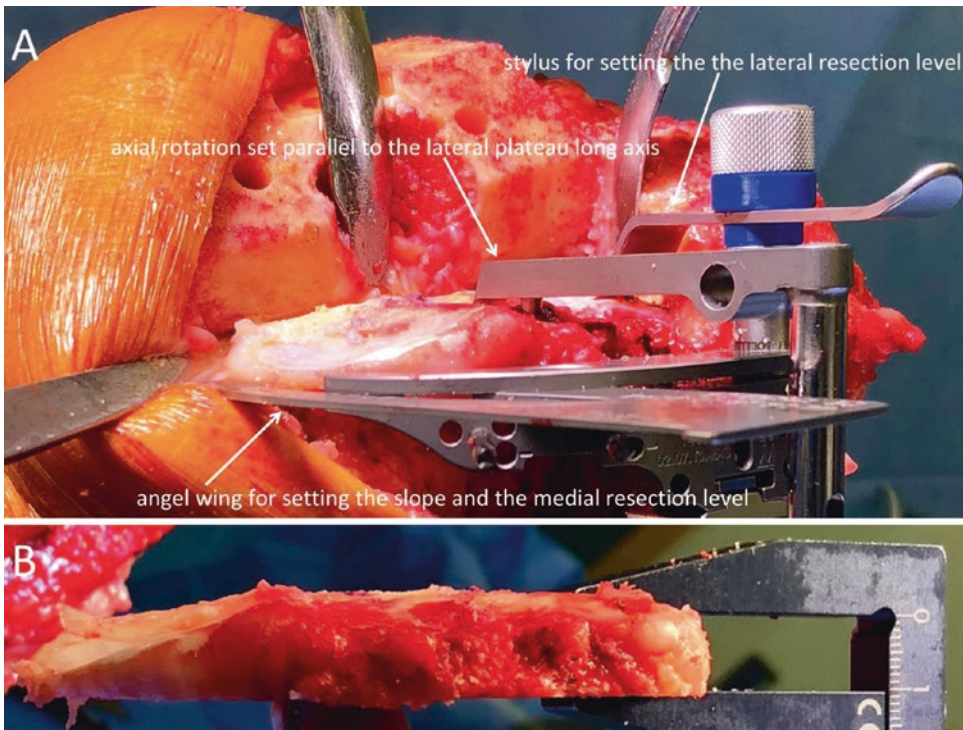

Fig. 16.13 Intra-operative photos illustrating the instrumentation setting to perform a kinematic tibial cut (**a**) and the quality assessment of the tibial cut with use of a caliper (**b**)

The extra-medullary alignment guide was used to stabilise the tibial cutting guide (Fig. 16.13a) while setting its orientation with the use of an angel wing and stylus. The tibial cut was done economically medially as the exact amount of medial plateau bone loss was unknown. The tibial cut was measured, revealing 10 mm was cut laterally and 3 mm medially (Fig. 16.13b).

The flexion and extension gaps were assessed with the use of spacer block (Fig. 16.14). The 90° flexion gap was found tighter, notably medially (Fig. 16.14a), than the gap at 10° of knee flexion (Fig. 16.14c). A recut of the tibia for an additional 2° of slope was performed.

After cementation of the final components (Fig. 16.15), patella tracking was judged
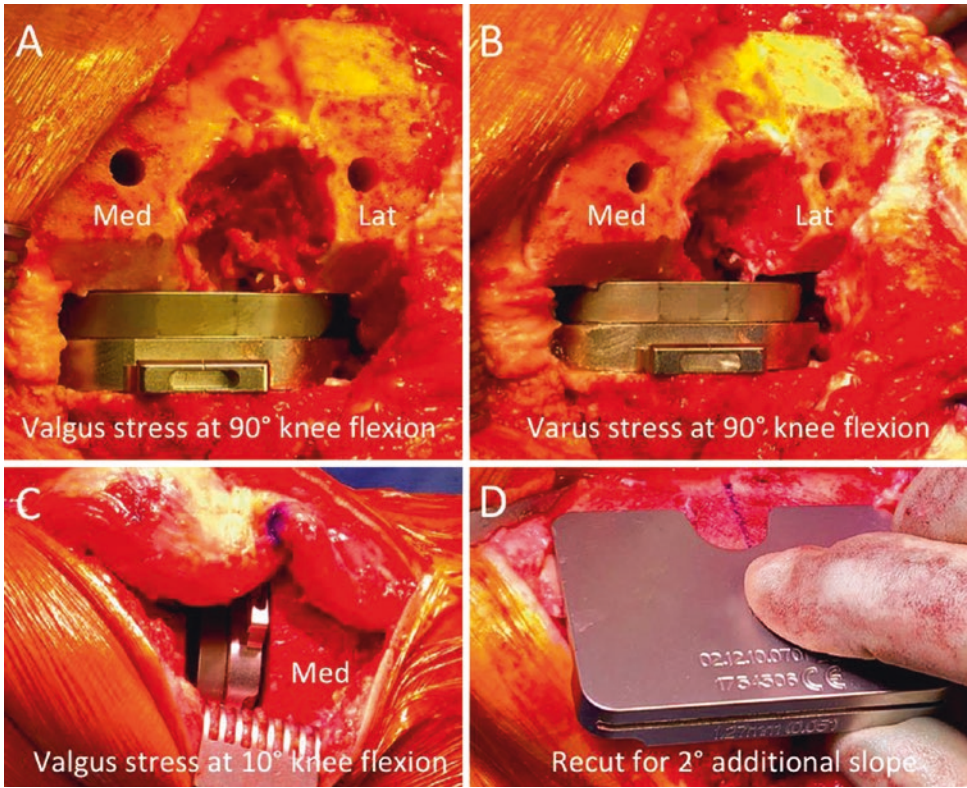
Fig. 16.14 Intra-operative photos illustrating the assessment of the residual femoro-tibial laxity with use of spacer block: medial (**a**) and lateral (**b**) knee compartment laxity in 90 degrees flexion, medial knee compartment laxity in 10 degrees flexion (**c**). As the adequacy of the femoral kinematic cuts was easily confirmed by quality check (calliper) and the femoro-tibial flexion gap was found excessively tight both medially and laterally, it was decided to recut the tibia inorder to slightly increase the slope (**d**)
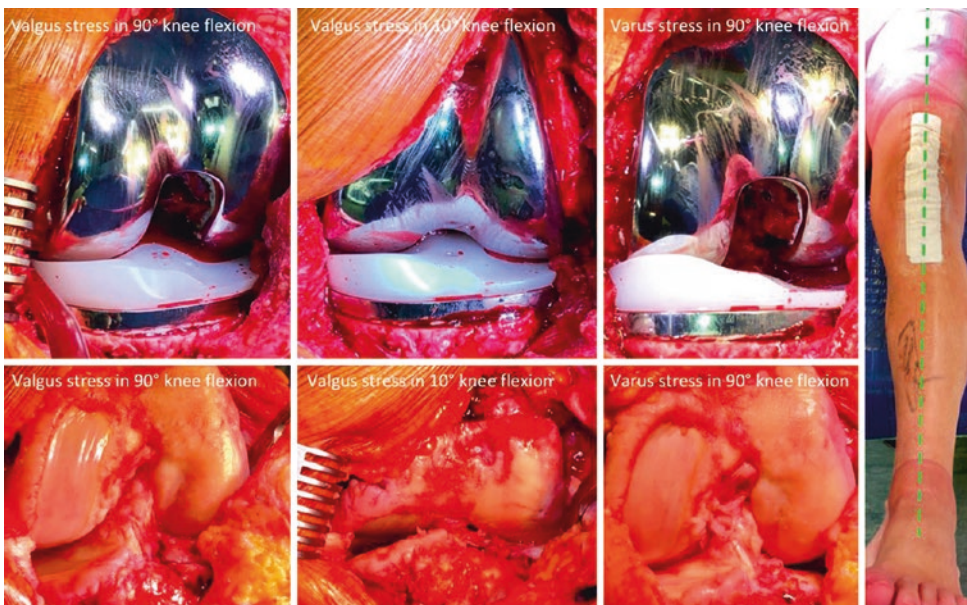
Fig. 16.15 Intra- and post-operative photos illustrating the pre- and post-implantation femoro-tibial laxities and the prosthetic lower limb alignment, respectively
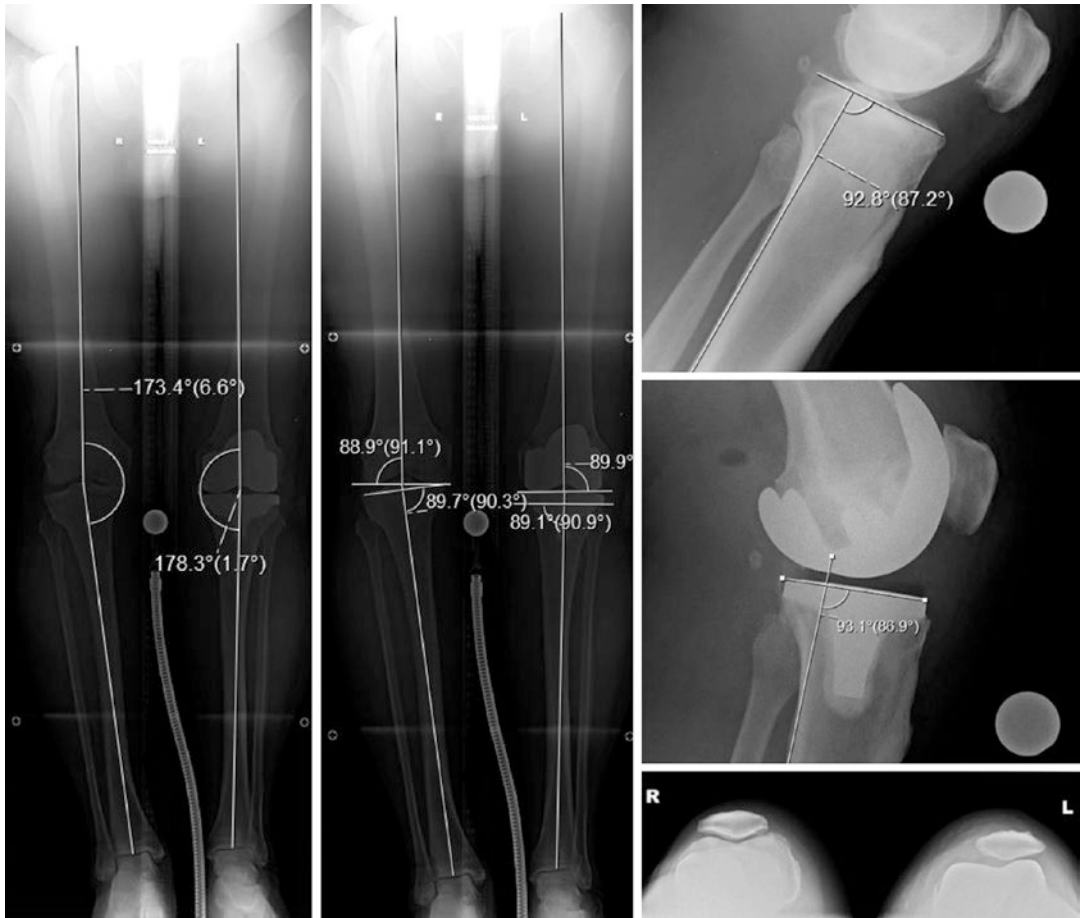
Fig. 16.16 Limb and knee radiographs. Post-operative long-leg radiographs with measurment of limb alignment (left long-leg radiograph) and components alignment relative to the femoral and tibial mechanical axis (right long-leg radiograph) suggesting adequat restoration of the constitutional frontal limb and knee alignment. Pre- and post-operative lateral knee radiographs confirming the adequat restoration of the individual tibia slope. Post-operative skyline view showing slight lateral patella shift at early knee flexion

excellent with no tilt or shift, full knee range of motion was restored, the limb looked neutrally aligned, and assessment of knee laxities showed a constant 2 mm medial and 4 mm lateral laxity throughout the all range of motion. There was no mid-flexion excessive laxity, and no residual laxity was present in full extension. The prosthetic and preoperative knee laxities were close (Fig. 16.15).

On postoperative radiographs (Fig. 16.16), the limb frontal alignment was 178°, and the distal femoral and proximal tibial articular surfaces orientations were restored within 1° from native orientations. On the skyline view, there was a slight lateral shift of the unresurfaced patella.

At 6 months follow-up, the patient was pain-free with an Oxford Knee Score at 42 and a satisfaction at 95/100.

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