

# Total knee arthroplasty at a crossroads: choosing the middle way

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*Anatomical total knee arthroplasty alignment versus conventional mechanical alignment; or a combination?*

## INTRODUCTION

Total knee arthroplasty (TKA) surgery faces a dilemma. The established method of alignment to the mechanical axis results in excellent implant longevity, but with less than ideal clinical functional and pain outcomes for some patients. A relatively recent development has been the concept of TKA implant positioning according to individual patient anatomy (also known as 'kinematic' alignment). There is evidence that anatomic individualised TKA implant positioning results in markedly improved functional outcomes. However, the methods published so far involve implant positioning that is not consistently aligned to the mechanical axis. Therefore, there is some justified concern that improved function is being achieved at the expense of compromised, long-term durability.

Conventional TKA creates resections according to the mechanical axis. Intra-operative releases and post-operative physiotherapy adapt the soft tissue to comply with the implant

position and biomechanics. The outcome of this process can be variable. Anatomic individualised TKA 'resurfaces' the knee articulation so that the implants are in congruity with soft-tissue biomechanics at the onset. This means less need for soft tissue adaptation and less likelihood of stalled rehabilitation.

The rationale behind the concept of anatomic individualised TKA is becoming more widely accepted, and the 'best of both worlds' can be achieved (Table I).

## BACKGROUND

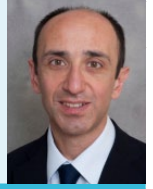
Total knee arthroplasty is one of the most successful and widely-performed surgical procedures in the world. Annually, 80 000 cases are performed in England and Wales<sup>1</sup> and The National Institute for Health and Care Excellence (NICE) considers interventions costing less than £20 000 per QALY to be cost-effective.<sup>2</sup> A study by Dakin et al<sup>3</sup> calculated TKA to cost £5 600 per QALY, which is well below this threshold; the

same conclusion was reached in Scotland.<sup>4</sup> Therefore, there is a justification for the increasing number of TKA performed. However, in the USA, over 700 000 TKA are performed annually, a figure that is expected to increase by 673% to 3.48 million annually by 2030.<sup>5</sup> The overall health economic burden of TKA in all countries is enormous, placing further importance on the surgeons' ability to perform the operation as well and with as little cost as possible. The success of the operation can be defined in terms of the durability of the implant and also the quality of the clinical outcome.

## MEASURING THE OUTCOME OF TKA

### Durability

The National Joint Registry of England and Wales (NJR)<sup>1</sup> records a ten-year revision rate of less than 3% for the most commonly-used and best TKA implants aligned according to established conventional techniques. Aseptic loosening is an indication in 1.4/1000 patient years



**Table 1.** Anatomic individualised total knee arthroplasty: key points

<ul style="list-style-type: none"> <li>• <i>Conventional</i> TKA alignment results in good implant durability, but with limited functional outcome. Greater anatomical alignment improves outcome.</li> </ul>
<ul style="list-style-type: none"> <li>• <i>Conventional</i> TKA alignment makes several approximations and relies on soft tissue adaptation, which may contribute to its limitations.</li> </ul>
<ul style="list-style-type: none"> <li>• <i>Anatomical</i> alignment ‘resurfaces’ the knee and achieves better congruency between soft tissue and implant biomechanics, and hence an improved functional outcome.</li> </ul>
<ul style="list-style-type: none"> <li>• However, the methods for anatomical alignment previously described involve using <i>symmetric</i> implants to resurface an <i>asymmetric</i> femur. This results in oblique implant positioning, raising concerns that durability may be compromised.</li> </ul>
<ul style="list-style-type: none"> <li>• The salient features of anatomical alignment that correspond better with soft tissue biomechanics include:             <ul style="list-style-type: none"> <li>◦ Aligning to the natural coronal axis of the limb within a safe range, rather than the neutral mechanical axis</li> <li>◦ Aligning implants to the anatomical distal femoral axis of rotation</li> <li>◦ Observing the differing levels of the medial and lateral joint lines</li> <li>◦ Making allowances for cartilage wear in measuring resections</li> <li>◦ Maintaining the spatial relationship between lateral femoral condyle and patella</li> <li>◦ Reproducing the anatomical posterior femoral offset and tibial plateau sagittal slope</li> <li>◦ Overall, maintaining the spatial relationship between the femur, tibia and patella and hence minimising the requirement for soft tissue releases and post-operative adaptation</li> </ul> </li> </ul>
<ul style="list-style-type: none"> <li>• An ideal mix of both considerations would combine stable implant positioning with the beneficial features of anatomical alignment.</li> </ul>

revisions; soft-tissue problems such as instability and stiffness are an indication in 0.73 and 0.39 revisions/1000 patient years respectively. Revisions for symptomatic TKA that have not failed are only carried out for extreme cases. The incidence of revisions for soft-tissue problems is likely to under-represent the prevalence of this type of symptomatic TKA, as revisions in this circumstance are known to have variable results and surgeons are widely hesitant to perform them.

**Clinical outcome**

This can be measured in terms of overall patient satisfaction and large-scale surveys in England and Wales,<sup>6</sup> Canada,<sup>7</sup> Sweden<sup>8</sup> and the New Zealand Joint Registry<sup>9</sup> have all produced similar findings of around 80% satisfaction. A more objective assessment of functional improvement can be made using a validated domain-specific scoring system such as the Oxford Knee Score (OKS). This is measured nationally in England and Wales<sup>10</sup> and shows an overall improvement of 16 points at six months. This contrasts with a 20 point improvement for THA with the Oxford Hip Score (OHS). It must be

remembered, however, that although the OHS and OKS are designed to be reliable and responsive, they are unlikely to be point-for-point comparable across the whole range.

Nam et al<sup>11</sup> surveyed patients in the United States following TKA. They looked for the prevalence of a knee that felt ‘normal’ and found it to be 66%. There was no relationship between the type of implant or alignment method and the status of ‘normality’, with only one exception: the so-called ‘kinematic’ method of alignment. This correlates with significantly improved clinical outcomes following TKA with contemporary implants, described for ‘kinematic’ alignment by Dossett<sup>12</sup> and Howell.<sup>13</sup> Dossett showed a seven point OKS advantage for the ‘kinematic’ group over traditional alignment at one year. The minimum clinically important change when comparing groups of patients is five points.<sup>14</sup> Thus, it appears that there is the potential to improve the clinical outcome of TKA. However, the method employed by Dossett and Howell is no longer available and it involved implanting the tibial component oblique to the mechanical axis, raising concerns over implant durability. Nonetheless, there remains a strong interest in reproducing these results by other means.

**BIOMECHANICAL CONSIDERATIONS**

The knee joint, in common with other joints, can be considered as a composite of the hard articulation and the soft-tissue envelope, which function together as one biomechanical unit. In the native healthy joint, there is absolute congruency between the biomechanics of the hard articulation and the soft tissue envelope. Typically there is some laxity of the lateral soft tissue in flexion<sup>15</sup> and tautness of most structures in full extension. If the hard articulation undergoes prosthetic arthroplasty, it is necessary to maintain the congruency between the articulation and the soft-tissue biomechanics for good function. Soft tissue placed under tension causes pain and stiffness (Fig. 1). Excessive laxity causes symptomatic instability<sup>16</sup> and also instability-related pain.

The femur, tibia and patella have a complex dynamic spatial relationship with each other, maintained by the soft-tissue envelope, which imparts stability whilst permitting controlled motion. A well-functioning TKA would, therefore, resurface the joint without disturbing the spatial relationship between the bones of the joint, and hence without introducing excessive laxity or tension to the soft-tissue envelope.





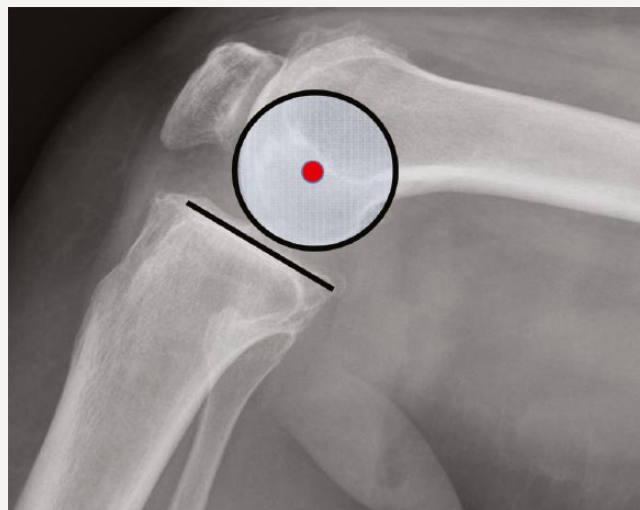
**Fig. 1** The tight knee arthroplasty: applying tension to musculoskeletal soft tissue causes pain.

Anatomical studies by Freeman<sup>17</sup> Monk<sup>18</sup> and Eckhoff<sup>19-21</sup> allow a conceptual mechanical model of the knee to be described. Each femoral condyle has a particular radius, and the medial condyle is larger than the lateral in most subjects with individual unique variation. Knee flexion occurs around a single axis passing through the centres of both condyles (Fig. 2).

Given that the two condyles have different and unique radii, the axis is also in a unique position, which is *not*, therefore, parallel with the surfaces of the condyles (unless the patient happens to have femoral condyles of equal radii; Fig. 3). For the typical patient, the medial femoral condyle with a larger radius will articulate with a lower medial tibial plateau, relative to the lateral tibial plateau.

Komistek<sup>22</sup> showed that knee rotation around a longitudinal axis during flexion is a product of differential rollback of the femoral condyles, and occurs around the medial compartment (the medial pivot principle). Eckhoff<sup>19-21</sup> demonstrated that medial pivot rotation is still consistent with femoral condyles functioning as cylinders. Komistek<sup>23</sup> also showed however that only half of TKAs exhibit medial pivot motion.

In extension the femoro-tibial articulation makes maximal contact at a point approximately



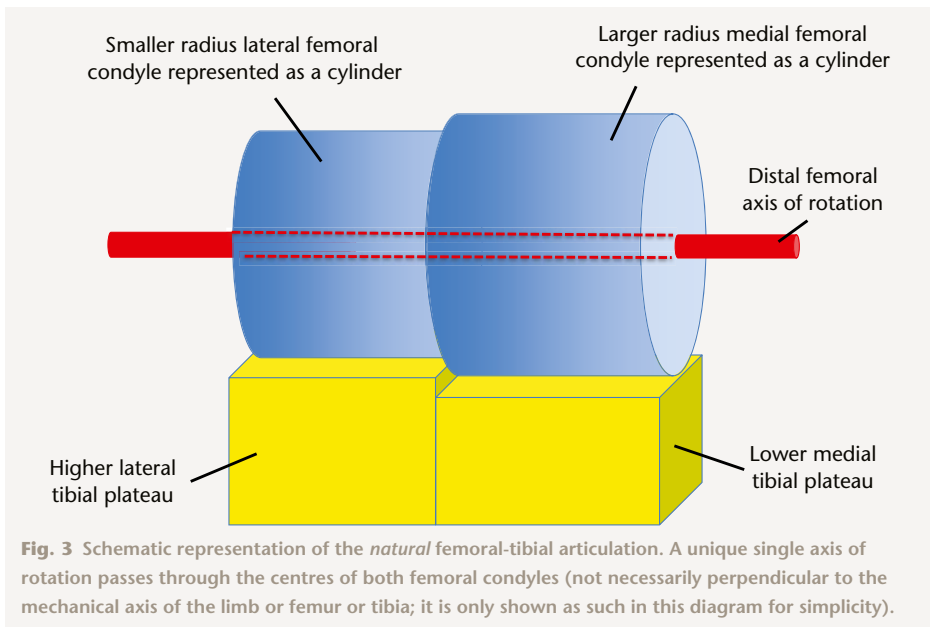
**Fig. 2** Femoral-tibial articulation follows a circular path around the distal femoral rotation axis.

one-third along the anterior-posterior axis of the tibial plateau (Fig. 4).

In 90° of flexion, the point of maximal contact rolls back to approximately two-thirds along (Fig. 5). The collateral ligaments maintain physiological tension in accordance to the spatial relationship between femur and tibia through this natural path of motion. If the sagittal posterior slope of the tibial plateau or the posterior offset of the femoral condyles were

altered, the spatial relationship between the femur and tibia would change, affecting the soft tissue tension in flexion.<sup>24</sup>

The spatial relationship between patella and lateral femoral condyle and motion of the patella-femoral joint follows another conceptual cylinder in the distal *lateral* femoral condyle and trochlea,<sup>18</sup> also restrained by the soft-tissue envelope of the knee. The anatomical features of the knee that drive the biomechanics follow



well-understood principles; however, the positions of the axes are unique to each knee.

#### The limb axis

Conventionally, a neutral mechanical axis of the limb has been described passing through the centres of the hip, knee and ankle<sup>25</sup> (Macquet's line) and traditionally TKA surgeons have sought to position the prosthesis perpendicular to this, with the aim being symmetrical and perpendicular implant-loading, with a mostly stable compressive force being applied during stance phase at the implant-bone interface (+/- cement) (Fig. 6). There are, however, some further considerations. Healthy subjects exhibit a unimodal distribution of lower limb alignment as a typical biological variable. The mean alignment of healthy knees is in fact about 2° of varus (more varus for men)<sup>26</sup> with several degrees of variation. Even if the mechanical axis is described in the anatomical position, during gait the limb itself is loaded in a variety of angles, mostly varus (given that when patients walk, they tend to place the feet nearer to the midline than in the anatomical position). On the other hand, obesity (increasingly a feature of patients undergoing TKA) holds the thighs apart, imparting a more valgus posture. This variation means that the TKA implant is subjected to loading within several degrees either side of the neutral mechanical axis.

#### Constitutional malalignment as a risk factor for osteoarthritis and implant failure

It is a commonly-held belief that constitutional varus or valgus beyond a few degrees is a risk factor for the development of osteoarthritis (OA), and surgeons have sought to 'correct' alignment to the neutral mechanical axis, lest the implant succumb to the same fate. The evidence for this phenomenon is scant. Pathogenesis of OA is multifactorial, and meniscal tears earlier in life are a significant risk factor.

Parratte<sup>27</sup> and others have studied the link between implant durability and limb alignment. They showed that contemporary TKA implant failure at 15 years is associated with alignment beyond 8° from neutral, but not smaller amounts of angulation. However, one needs to allow for the inaccuracy in instrumentation and measurement error (usually around 3°).

#### LIMITATIONS OF CONVENTIONAL TKA TECHNIQUE

##### Limb alignment

Conventional TKA technique is directed at the 'typical' knee and makes certain assumptions concerning coronal limb alignment:

- *In extension, distal femoral and tibial resections are made perpendicular to the perceived neutral mechanical axis. It is assumed that this will produce a*

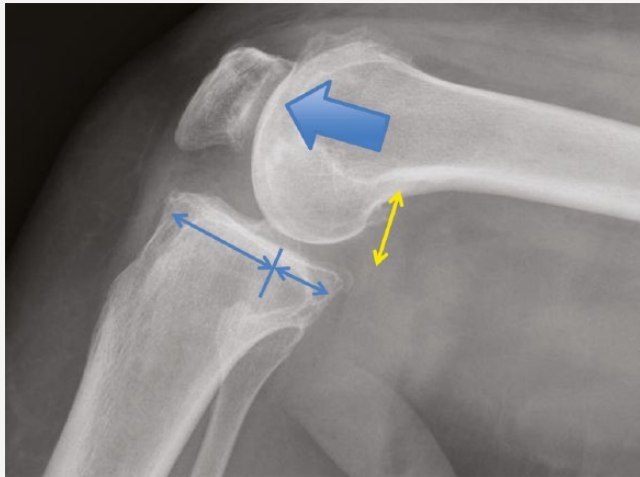


**Fig. 4** In extension the femur articulates with the tibia at the 1/3 posterior position.

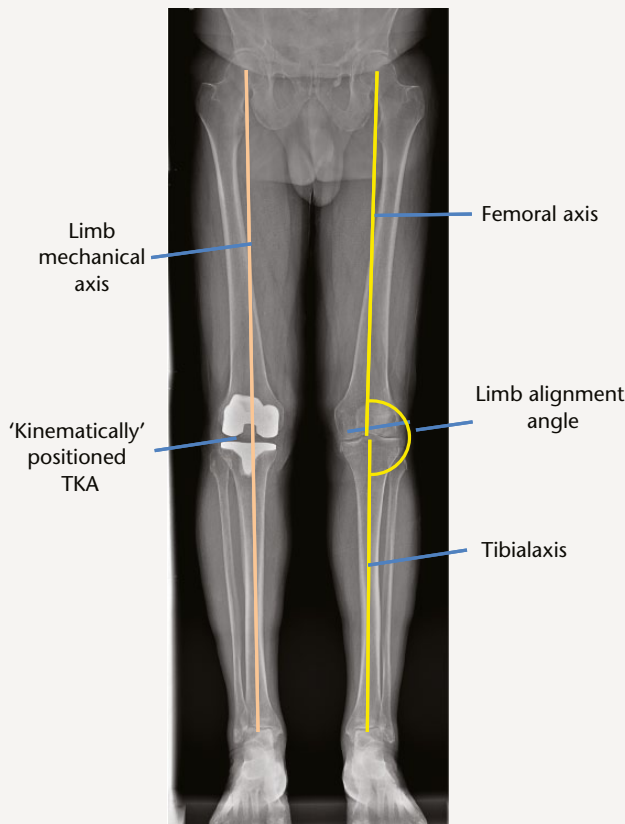
*rectangular (i.e. balanced) extension gap.* However this would only be the case if the patient truly had a neutral axis (which only a minority do) and the resections were accurate.

- *If the standard resections do not produce a rectangular extension gap, this is due to ligament contracture or stretching.* This may sometimes be the case, but an alternative explanation is that the patient may simply have had a constitutional varus or valgus limb or there may be some inaccuracy in the resections.
- *Ligament releases are required to 'match' the soft tissue to the resections.* In fact the surgeon is sometimes making unnecessary soft tissue releases in order to change the otherwise normal soft tissue to comply with any inaccuracy in the resections or to change an acceptable small degree of constitutional varus or valgus to comply with the resections.

Given that most limbs have a constitutional varus posture, conventionally the surgeon will make resections according to a neutral



**Fig. 5** In flexion, the patella articulates with the distal aspect of the lateral femoral condyle and trochlea. Distalisation of the lateral femoral condyle exerts pressure against the patella and soft tissue envelope. The femur articulates with the tibia at the 2/3 posterior position. The posterior femoral offset is shown by the yellow arrow.



**Fig. 6** The axes of the lower limb and a 'kinematically' positioned TKA, corresponding to the differing heights of the medial and lateral compartments but not perpendicular to the limb mechanical axis.

mechanical axis and release and lengthen the medial collateral ligament (MCL) in order to balance the knee in extension. However, the same release may unhelpfully impart imbalance in flexion, especially if a measured resection method is used for the flexion gap.

#### **Conventional TKA joint line restoration**

The tibial resection is usually measured from the less worn lateral compartment and is perpendicular to the tibial axis in the coronal plane.

Most patients have a lateral compartment that is higher than the medial. Thus conventional technique resects less than implant thickness from the medial tibial plateau thereby raising the medial joint line with the implant (Fig. 7a). In effect the tibial implant is positioned according to the lateral compartment joint line.

Meanwhile the distal femoral resection is measured using jigs that rest against the more prominent medial femoral condyle (Fig. 7b). Thus the resections overlap (Fig. 7c) and are also subject to individual anatomy and surface wear. Joint line restoration is therefore approximate. Restoration of the joint line directly correlates with function<sup>46</sup> and is not optimal with conventional TKA technique.

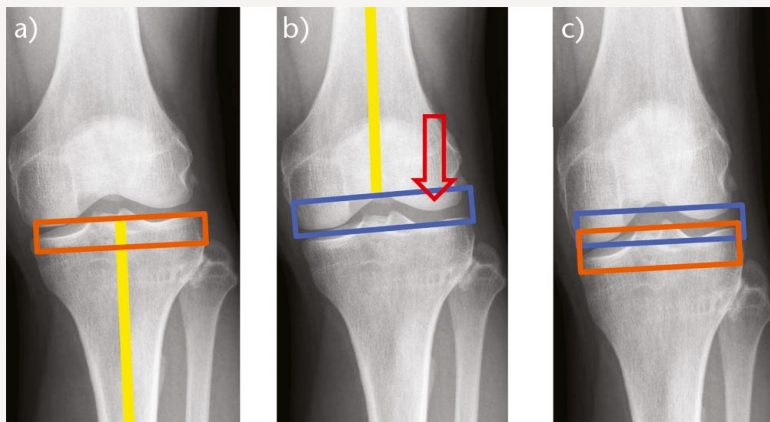
The distal lateral femoral condyle resection is thinner than implant thickness and leads to distalisation of the lateral femoral condyle with the femoral implant [Fig. 8]. This imparts pressure against the patella in flexion and hence the lateral soft tissue. This can contribute to lateral soft tissue tension, pain and limitation to flexion (Fig. 9).

#### **Conventional TKA flexion gap**

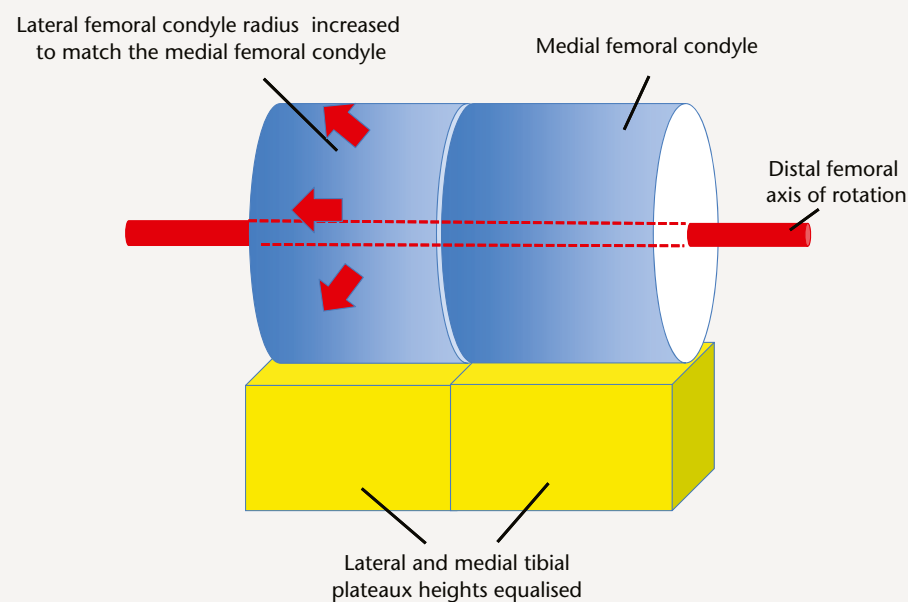
Typically patients have a lateral femoral joint line that is higher than the medial equivalent to 3° of angulation relative to the tibial axis. Having made a 'flat' tibial resection, the most commonly used conventional method (measured resection) introduces an arbitrary 3° of external rotation to the femoral component position, in order to compensate and achieve a balanced flexion gap. However, if the patient has a different coronal joint slope, the arbitrary 3° will not result in a balanced flexion gap (Fig. 10). Wear of the posterior femoral condyles also affects posterior referencing jigs as does medial or lateral release performed for the benefit of the extension gap. Balanced flexion gap resection is possible but when used in conjunction with otherwise standard conventional technique, there is no evidence to show an improved overall outcome.

#### **Conventional TKA tibial resection posterior slope**

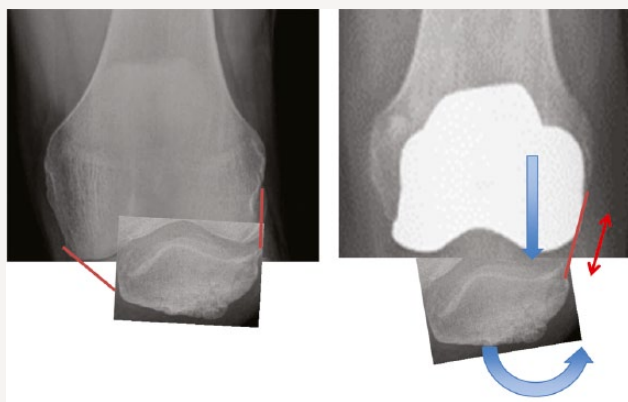
This is usually arbitrary and surgeons will either use the implant manufacturer's recommended slope, or have their own preference. If the tibial resection that is made is less steep than the native anatomy, the size of the flexion gap is reduced and vice versa (Fig. 11).



**Fig. 7** a) Conventional technique resects less than implant thickness from the medial tibial plateau, raising the medial joint line with the implant; b) the distal femoral resection is measured using jigs that rest against the more prominent medial femoral condyle; c) overlapping resections.



**Fig. 8** Schematic representation of *conventional* TKA technique – The radius of the lateral femoral condyle is increased to match the medial femoral condyle. This can impart more tension on the patella and the soft tissue envelope.



**Fig. 9** Distalisation of the implant lateral femoral condyle exerts pressure against the patella.

If the posterior femoral resection is a measured resection and hence fixed, the soft tissue tension in flexion will not necessarily be optimal.

### Computer navigation

This uses the same principles as the conventional TKA methods but imparts greater accuracy.<sup>28-30</sup> It has not been shown to improve the functional outcome.<sup>31-33</sup> This suggests that accuracy of resection alone will not improve functional outcomes.

### Patient-specific instrumentation (PSI)

Used as an alternative method of achieving conventional alignment, these devices do not offer any benefit in terms of alignment or clinical outcome.<sup>34</sup> A comprehensive review concluded that available evidence did not show any overall benefit at all with PSI.<sup>35</sup>

### IN SUMMARY

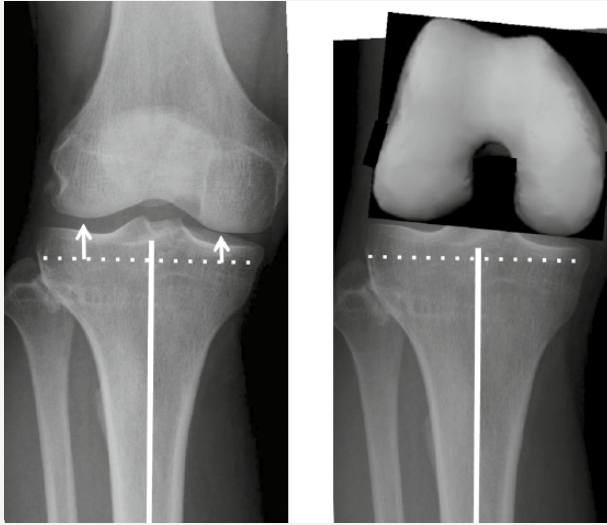
Conventional TKA alignment makes certain assumptions and approximations and does not reproduce natural knee anatomy or biomechanics as faithfully as could be achieved. It also relies on soft tissue releases and post-operative soft tissue adaptation, which can be unpredictable. We can hypothesise that these limit the average functional outcome and may produce poor outcomes for some patients especially patients with atypical anatomy, whom the usual ‘recipe’ does not suit.

### THE CASE FOR ANATOMICAL LIMB ALIGNMENT

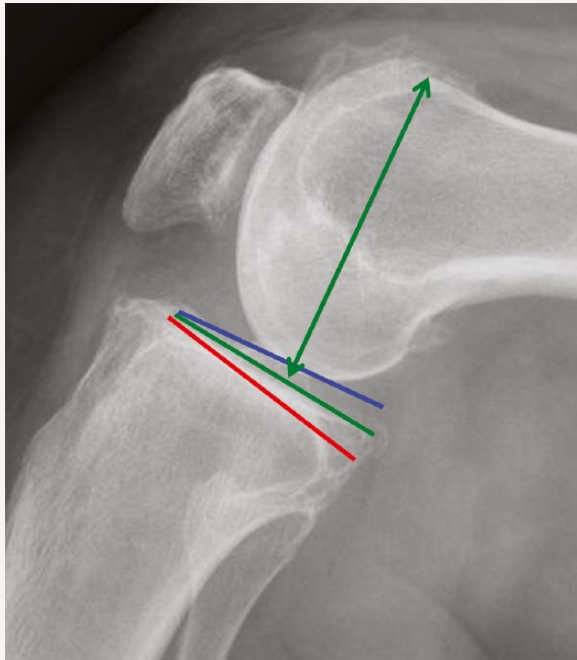
Resection angles can be individualised to the constitutional axis of the patient. Many surgeons already resect the tibia perpendicular to the tibial axis and then vary the distal femoral resection to ‘gap-balance’ the extension gap. Some authors make anatomical tibial and distal femoral resections.<sup>12,13</sup> In both cases the tibial and femoral components are not necessarily aligned to the overall limb mechanical axis, however, the former method appears to have greater acceptability in review articles probably because there is evidence that excessive varus tibial component positioning is a risk factor for loosening.<sup>36</sup>

The limitations of this approach are as follows:

- The surgeon is assuming that the soft tissue remains in its pre-disease state. In fact in the presence of even moderate



**Fig. 10** The larger radius medial femoral condyle articulates with the lower medial tibial plateau in extension (left) and flexion (right). A tibial resection perpendicular to the tibial axis (dotted line) resects less bone from the medial tibia. In flexion the femoral component is conventionally placed in 3° external rotation relative to the posterior femoral condyles in order to compensate, however, this is only accurate for the typical patient and not every patient as there is individual variation in the discrepancy between the joint level heights.



**Fig. 11** The flexion gap: the spatial relationship between femur and tibia in flexion is a product of the femoral AP size (including posterior femoral offset) and a matching tibial plateau height and posterior slope (green). If the tibial plateau is made more steep (red line) laxity results, less steep (blue line) results in tension.

acquired deformity, stretching or contracture of soft tissue may have occurred and soft tissue guided alignment may not reproduce pre-disease anatomy.

- *If aligning to the constitutional axis, some patients will have extreme alignment. This may result in TKA alignment outside an acceptable range. There would*

need to be a measure to ‘moderate’ and still make releases for outliers.

### THE CASE FOR ANATOMICAL IMPLANT POSITIONING

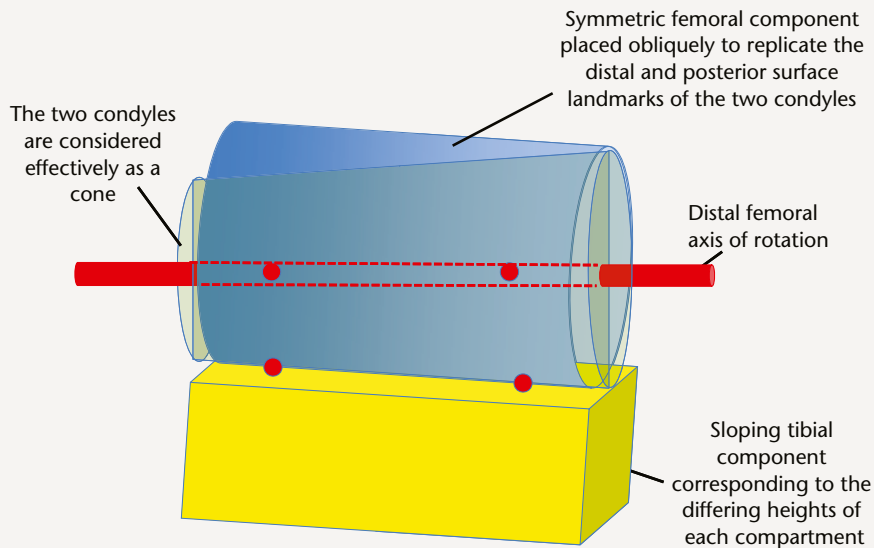
The intention of anatomic implant positioning is to perform a ‘resurfacing’ and thereby position the implants according to the anatomy of the individual patient, which by definition will be congruent with the soft tissue biomechanics and hence may produce better functional outcomes.

The evidence for the improved outcome is using a technique called ‘ShapeMatch’ made available by Stryker but then withdrawn<sup>37</sup> due to regulatory issues and poor outcomes in some outliers in terms of acceptable overall alignment.<sup>13</sup> Nevertheless, the technique did produce markedly improved *average* functional outcomes, and interest remains strong in achieving this with alternate means.

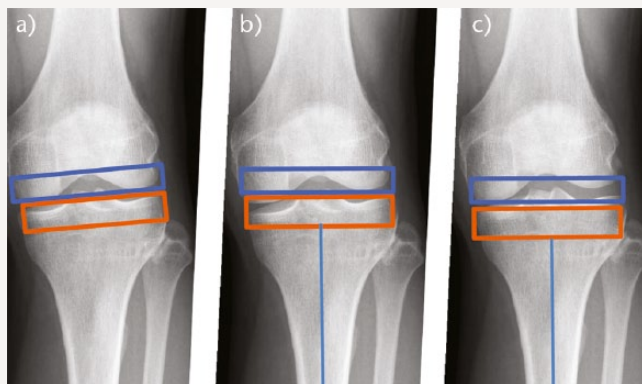
The ‘ShapeMatch’ technique (also known as *kinematic* alignment) involved a pre-operative MRI, computed extrapolation of the pre-disease anatomy and patient-specific pinning blocks to make resections such that the implants would have the same articular surface interfaces as the pre-disease knee (Fig 12).

The limitations were:

- *It assumed that the soft tissue remained in the pre-disease state such that good balance would be achieved with pre-disease hard articulation positioning. In reality it is likely that some soft tissue stretching or contracture occurs in arthritic knees and releases made for the surgical approach will also have an effect. Extent of osteophyctomy is surgeon-dependent.*
- *A symmetrical implant was being used to resurface an asymmetric distal femur. To achieve this, the femoral component was usually in internal rotation, placing the trochlea in a medialised position.*
- *‘Sloping’ implants in the coronal plane relative to the tibial and limb axes. Marked angulation and asymmetric implants loading may be detrimental to durability.*
- *The methodology for the determination of the posterior slope of the tibial component and relating this to the posterior femoral offset was not explained.*



**Fig. 12** Schematic representation of 'kinematic' alignment. The femoral and tibial component are placed obliquely for distal and posterior surface landmarks to conform to the native anatomy. The lateral femoral condyle is not distalised, avoiding patella and soft tissue tension. The single axis of rotation still continues to function in the usual range of movement with the implants behaving as a true resurfacing within the range.



**Fig. 13** The surgeon has three means of joint line restoration. a) 'kinematic' – sloping resections passing through both joint lines; b) perpendicular resections centred on the lateral joint line (the medial femoral condyle is downsized to match the lateral); c) conventional TKA resections centred on the medial joint line (the lateral femoral condyle is upsized to match the medial femoral condyle).

### 'KINEMATIC' TKA POSITIONING BY OTHER MEANS

In a bid to replicate these results surgeons have devised alternative methods. Unconventional application of conventional instruments<sup>38</sup> and modified computer navigation technique<sup>39</sup> have been described and some manufacturers (including Stryker) are developing new instruments for kinematic alignment. Such techniques can be successful but 'off-piste' surgery adopted by non-experts can be expected to carry a higher error rate. Femoral-tibial

biomechanics are relatively easy to achieve with these techniques, but not patella-femoral biomechanics. Overall, some patients still achieve poor outcomes.

### CONSENSUS ON 'KINEMATIC' ALIGNMENT

A majority of review articles<sup>40-43</sup> have concluded that there is insufficient evidence for the safety of 'kinematic' implant positioning in terms of the potential detrimental effect on durability, and advise against the application of such methods until further evidence is available.

Currently there is only one published follow-up of six years.<sup>44</sup>

### CUSTOM IMPLANTS

For a 'true resurfacing' of the knee which is an individual and asymmetric structure, Conformis<sup>45</sup> offer a custom-made TKA implant coupled with PSI kinematic alignment. However, this process adds to the cost of the procedure and has been carried out in relatively small numbers.

### MORE ANATOMICAL MASS-PRODUCED IMPLANTS

Some manufacturers have produced new TKA implants which claim to improve biomechanics by virtue of being closer replications of normal anatomy.<sup>47-49</sup> An implant design better based on the anatomy of the typical patient may improve the 'hit-rate' of conventional TKA technique; however the magnitude of this benefit is not known as clinical outcomes have not yet been published for these implants. Even with a superior implant, anatomical individualised alignment may further reduce or eliminate biomechanical outliers.

### THE WAY FORWARD

The benefits of anatomical individualised alignment on soft tissue handling should be achievable without deviating greatly from the reassurance of symmetrical implant positioning and loading.

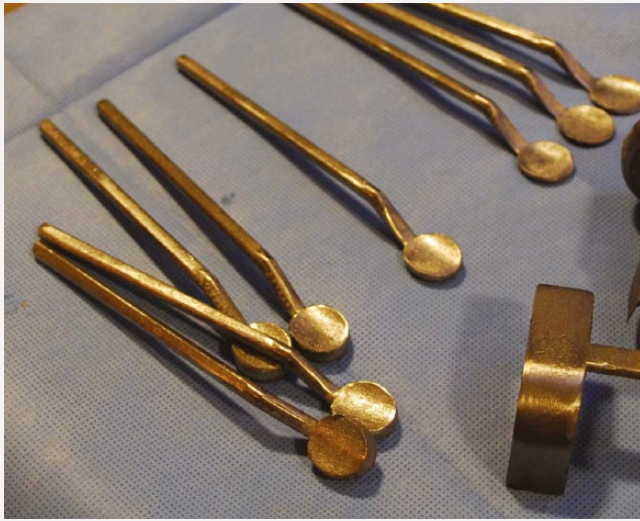
### IDENTIFYING THE BENEFICIAL COMPONENTS OF ANATOMIC ALIGNMENT

The aim is achieving congruency between the biomechanics of the hard articulation and the soft tissue envelope. This means performing TKA with minimal disruption to the spatial relationship between patella, femur and tibia, hence minimising reliance on soft tissue releases and post-operative soft tissue adaptation.

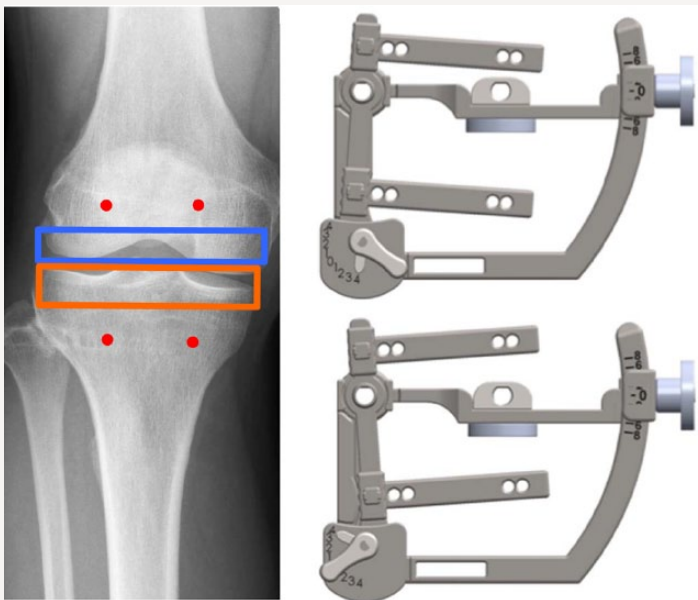
The components are:

- Aligning to the individual, within an acceptable range of up to 3° from the neutral mechanical axis.
- Accounting for the differing joint lines of each compartment.
- Allowing for 'wear' when measuring resection thicknesses.
- Equal and accurately balanced extension and flexion gaps.





**Fig. 14** ADVANTicS technique joint gap guides in a selection of thicknesses are introduced into the joint space vacated by eroded articular cartilage. The surgeon can ‘fine tune’ the tension in each compartment and identify the joint line from which resections are measured.



**Fig. 15** The default function produces a rectangular extension gap perpendicular to the tibial axis, of the correct size and centred on the lateral joint line (left). Kinematics can be optionally introduced in a controlled fashion to allow a compromise to be reached if there is a large discrepancy between the medial and lateral joint line heights (right).

- Restoring posterior femoral offset and for a correct flexion gap size relating to a matching tibial resection thickness and posterior slope.
- Avoiding distalisation of the lateral femoral condyle and consequent pressure against the patella.

#### CAN THESE CRITERIA BE ACHIEVED WITHOUT OBLIQUE IMPLANT POSITIONING?

Distraction of the knee to physiological soft tissue tension and performing ‘balanced resections’ measured implant thickness from the centre of the joint gap (i.e. the pre-wear

interface between the articular surfaces) allows implants to be positioned in a stable manner, perpendicular to the tibial axis.

#### ADDRESSING THE DIFFERING JOINT LINES OF THE TWO COMPARTMENTS

To position the implant in correspondence with both joint lines means *oblique* positioning (‘kinematic alignment’) (Fig. 13). To avoid this, the surgeon needs to either:

- Lower the higher lateral joint line (i.e. upsize the lateral femoral condyle radius). This is conventional TKA. It tensions the patellofemoral joint (PFJ) and lateral soft tissue.
- Elevate the lower medial joint line (i.e. downsize the radius of the medial femoral condyle). Coupled with a flat tibial resection (elevated medial tibial plateau), this maintains the anatomical spatial relationship between femur and patella.

#### ACCURATE FLEXION GAP - RELATING POSTERIOR FEMORAL OFFSET AND TIBIAL POSTERIOR SLOPE

Conventional TKA and even previously described ‘kinematic’ TKA have not achieved this priority to an optimum. In part this is because femoral component anterior–posterior (AP) sizes are incremental. Therefore, a stepless adjustment to flexion gap size is necessary to maintain an optimal flexion gap.

#### ANATOMIC INDIVIDUALISED METHOD OF TKA ALIGNMENT (ADVANTICS)

The ADVANTicS project (<http://advantictka.com/>) is designed to address some of the current constraints in total knee arthroplasty and proposes a novel surgical approach:

- 1) Osteophyctomy is performed and the knee is distracted in extension prior to any resections being made.
- 2) The joint gaps are thus opened up where articular cartilage has been lost. Joint gap guides (gauges) in 1 mm thickness increments are inserted into each compartment to ‘fine tune’ the tension in extension to feel physiological (Fig. 14). This means 1 mm incremental accuracy as is used for unicompartmental arthroplasty.
- 3) Measurement of limb alignment and correlation of gap sizes with cartilage loss allows the surgeon to determine if the knee

has an outlier alignment. This may be either due to ligament stretching/contracture or excessive constitutional limb malalignment. Releases may be performed if required to bring such knees into an acceptable range.

- 4) Pins for distal femoral and tibial resections are inserted simultaneously, ensuring a balanced rectangular extension gap centred on the *lateral* joint line (identified by the joint gap guides). The resections are by default perpendicular to the tibial axis but with the function to dial in controlled small degrees of varus to optimise for knees with constitutional limb varus (Figs 15 and 16).
- 5) The knee is then distracted in 90° of flexion. Pins are inserted for the femoral posterior and anterior resections, parallel with the tibial pins for a balanced flexion gap. This is coupled to an adjustment to the posterior slope of the intended tibial resection, ensuring a balanced flexion gap of the correct size for the nearest incremental size of femoral component for appropriate posterior femoral offset for the individual knee (Figs 17 and 18).

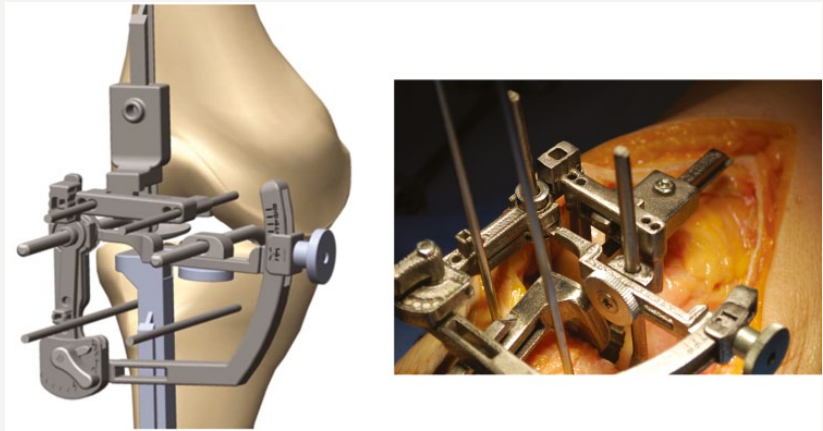
The net result is that the femoral component is positioned aligned with the distal femoral axis of rotation (Fig. 19) and the implants are positioned perpendicular to the tibial axis for symmetrical loading. The larger medial femoral condyle radius is effectively reduced to match the lateral condyle with a corresponding elevation of the medial tibial plateau. (Fig.20). Femoral component internal rotation is avoided. This maintains the cylindrical biomechanics of knee flexion and achieves the benefits of anatomical implant positioning without oblique implant positioning being necessary but with the possibility for controlled and moderated coronal angulation to account for individual anatomy.

#### CONFLICT OF INTEREST

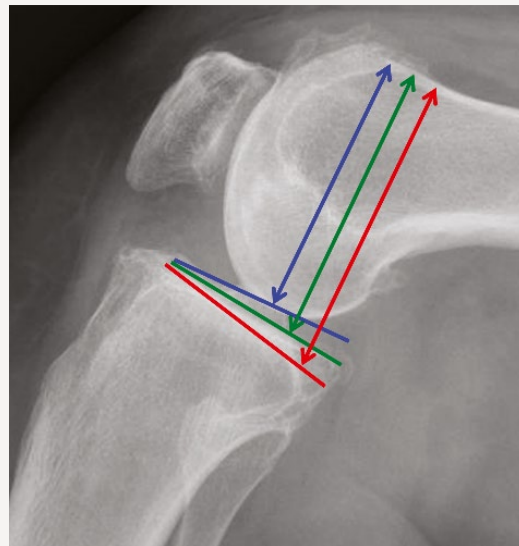
The author is directly involved in the development of ADVANTicS instrumentation. Both the author and institution have a commercial interest in this development.

#### NOTE

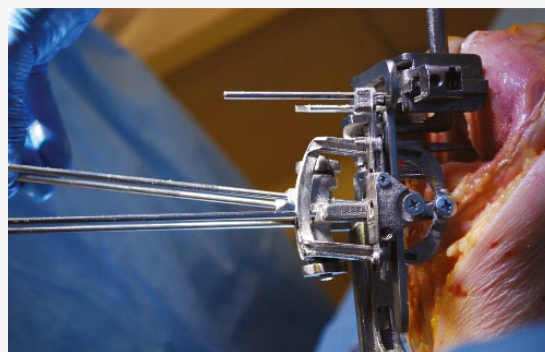
Surgeons interested in reading a more detailed explanation of the ADVANTicS technique or who wish to be involved with the project can visit: [www.advantictka.com](http://www.advantictka.com) for further information.



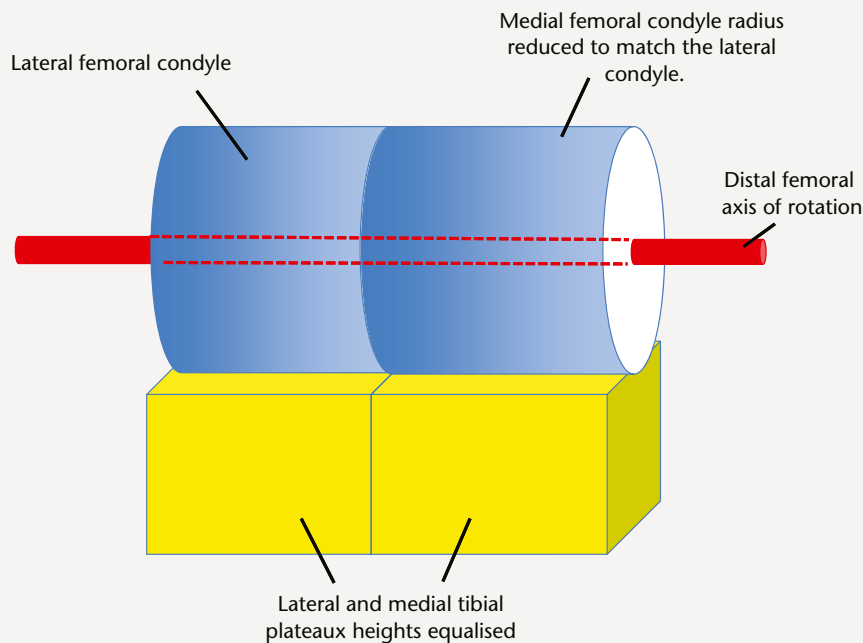
**Fig. 16** ADVANTicS system joint level finder connects onto joint gap guides and pins for tibial and femoral resections, simultaneously (cadaver).



**Fig. 17** The proposed ADVANTicS technique links the femoral AP size selection with a corresponding tibial posterior slope. The system selects the nearest available size of femoral implant and adjusts the tibial slope to 'fine-tune' the flexion gap to the optimal size.



**Fig. 18** ADVANTicS Flexion Gap Device. The femoral AP resections are interlinked with the tibial resection posterior slope for an optimised flexion gap size and femoral AP size (cadaver).



**Fig. 19** Schematic representation of the new anatomic individualised (ADVANTicS) technique. The larger medial femoral condyle radius is reduced to match the lateral condyle radius. Tension on the patella and soft tissue is avoided. The single axis of rotation passing through the centres of both femoral condyles remains unchanged and oblique implant positioning is avoided.



**Fig. 20** Reducing the radius of the medial femoral condyle and raising the medial tibial plateau proportionately does not alter the axis of rotation. The spatial relationship and the biomechanics between femur and tibia remain the same.

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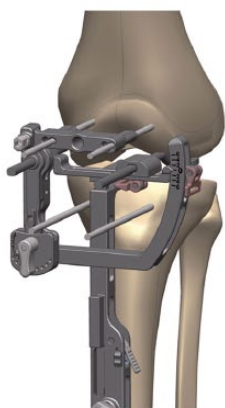
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