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Newer Coronal Alignment Philosophies in Total Knee Arthroplasty: A Brief Review

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Abstract

Total Knee Arthroplasty (TKA) surgeries have been one of the most successful surgeries over the past half a decade. However a substantial proportion of patients undergoing TKA have the feeling of their replaced knee being an 'unnatural one'. Also the conventional TKA requires the surgeon to maintain a coronal plane Hip Knee Angle (HKA) of 180 deg with the joint line being parallel to the horizontal and this requires a significant soft tissue release . Recently there are many different pre arthritic knee phenotypes been described with varying joint line obliquities and HKA angles. It is this difference of coronal HKA axis and joint line obliquity in the non replaced and the replaced knee that is believed to be the cause of dissatisfaction after TKA. Many coronal plane alignment philosophies have been reported to bridge this gap as mentioned earlier which replicate the pre arthritic knee anatomy with minimal soft tissue release. The only concern of the different philosophies is the long term implant survival when fixed in a non mechanically aligned position. However robotics have added a significant safety with calibrated execution to prevent outliers and improve implant survivorship. This is a brief review of the different coronal plane alignment philosophies in TKA.

Keywords: Coronal; alignment; dissatisfaction; HKA; joint line obliquity

Introduction

Coronal alignment in total knee arthroplasty (TKA) has gained increasing attention since it is considered to be an important factor to improve functional patient-reported outcomes. To resolve the problem of patient dissatisfaction and perception of "unnatural knee" after TKA, different alignment philosophies have been described with the purpose to better reproduce knee anatomy and kinematics. The premise is to maintain the pre arthritic hip-knee-ankle (HKA) axis and also the native joint line obliquity. This will enhance the feeling of a "natural knee" by less soft tissue releases and caliberated bone cuts only. The advent of robotics has given surgeons the luxury of accurately executing the philosophy that the surgeon believes in.

Nowadays different alignment philosophies can be classified in three main categories (Fig. 1 and Table 1) [1].

1. Systematic alignment: This means that all patients will receive this alignment irrespective of their pre-arthritic anatomy. This includes mechanical alignment (MA) [2-5] and anatomic alignment (AA) [6] with the goals to restore neutral alignment with HKA axis of 180° for all patients independently from pre-operative alignment;
2. Patient-specific alignment such as kinematic alignment (KA) [7] that aims to maintain the native limb alignment and joint line inclination.
3. Hybrid alignment such as restricted kinematic alignment (rKA) [8,9], inverse kinematic alignment (iKA) [8-10], adjusted mechanical alignment (aMA) [11-15], and functional alignment (FA) [16-18] with the aim to restore the coronal alignment within an HKA angle safe zone of 177–183°.

It is still to be proven whether change of alignment correlates with better functional outcomes or long-term implant survivorship. This paper intends to shed light on definitions of some of the alternative alignments in TKR.

MA

This philosophy was described by Ranawat and Insall in the 1970s and is the most widely used in TKA with well-documented long-term results. Here, both the femoral and tibial components are placed perpendicular to the mechanical axis. This philosophy allows a HKA angle of 180° after a proper ligament release. Neutral alignment guarantees symmetric balanced load distribution between the medial and

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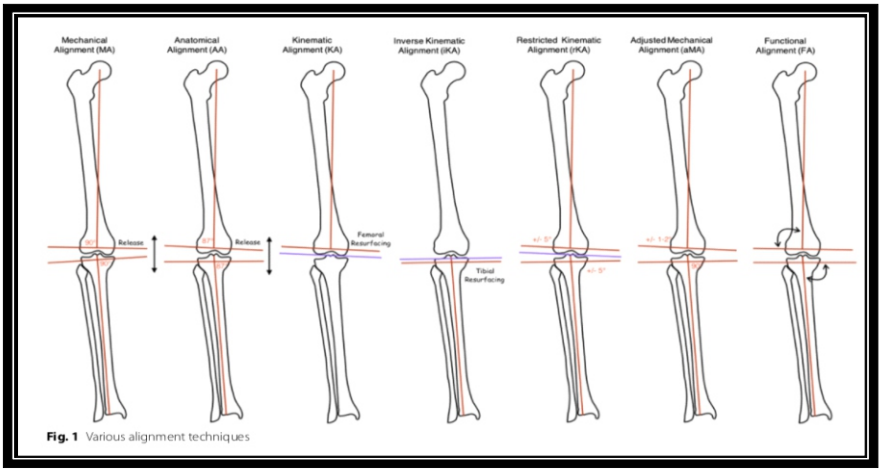

Figure 1: Various alignment techniques.

lateral compartments that minimize wear and potential component loosening. This introduced the "compromise of 3°" as the femoral component should be positioned with 3° of external rotation to balance flexion gaps with the extension gaps. This is the Gold Standard alignment philosophy with long-term implant survivorship between 89% and 99% at 10 years and between 85% and 97% at 20 years of follow-up. Even the clinical outcomes were significantly improved considering Oxford Knee Score, Western Ontario and McMaster University index, Knee Society Score, and range of motion [1].

What led to the thought process of seeking alternative alignment strategies was that some studies showed up to 20% dissatisfaction after TKA. The possible reason for this dissatisfaction could be the fact that MA is a systematic alignment where all limbs are aligned to a neutral HKA axis independent of the pre-operative alignment, which is considered "unnatural" by many patients. Bellemans et al. reported that more than 30% of male non-arthritic patients had a constitutional varus angle of >3°. Hirschmann et al. reported a wide distribution of femoral and tibial coronal alignment in young non-osteoarthritic knees.

AA

This philosophy was described by Hungerford and Krackow in 1880s to reproduce the "anatomic" oblique joint line after total knee replacement. Here too the aim was to achieve a HKA of 180 deg. But with a natural oblique joint line of 3 deg. This technique involved fixing the femoral component in 3° of valgus and the tibial component in 3° of varus relative to the mechanical axis of the limb. As the femoral and tibial components are placed in 3° of inclination, the need to externally rotate the femoral component to balance the flexion gap is obviated and the femoral component is aligned parallel to the posterior condylar axis. The advantage of this technique was thought that it required a lesser ligament release. However, that era did not have sophisticated jigs for caliberated cuts, leave alone technology like CAS or robotics. Hence, this technique was criticized on the basis of the technical difficulties in performing the varus cut on the tibia in a precise and reproducible way. The main concern with AA is that inadvertent over-resection of more than 3° in the proximal tibial cut may lead to excessive varus of the tibial implant, which is associated with premature component failure in TKA [19, 20]. Moreover, another important drawback with this technique was the use of first-generation tibial keel design that provided poor tibial fixation compared with the new-generation implants [21].

KA

In 2008, Howell et al. described this technique that aims to restore the pre-arthritic HKA angle, the pre-arthritic joint line obliquity, and natural tension of the ligaments, without a ligament release. The KA is a "true femoral resurfacing" where the femoral joint line level is restored by removing cartilage and bone thickness equivalent to the implant thickness. Since technology was not available then, this was called "calipered" technique since the use of caliper is essential for measuring the desired resection. The flexion and extension gaps are balanced consequently with the tibial resection. KA TKA restores the constitutional joint line on the femoral side and the physiological knee laxity without the need for soft-tissue release.

Table 1 Main key points in different coronal alignments philosophies

	Mechanical alignment (MA)	Anatomic alignment (AA)	Kinematic alignment (KA)	Inverse kinematic alignment (iKA)	Restricted kinematic alignment (iKA)	Adjusted mechanical alignment (aMA)	Functional alignment (FA)
Distal femoral cuts	90°	93°	Femoral resurfacing	According to extension gap	90 ± 5°	90 ± 2°	According to extension gap(± 3°)
Proximal tibial cuts	90°	87°	According to extension gap	Tibial resurfacing restricted to 84° (varus) to 92° (valgus)	90 ± 5°	90°	According to extension gap (± 3°)
Femur external rotation to PCA	3°	0°	Femoral resurfacing	According to flexion gap	According to flexion gap	3°	According to flexion gap
Overall alignment (HKA)	0°	0°	Native alignment	Slight undercorrection safe zone +6° varus to −3° valgus	Slight undercorrection safe zone +6° varus to −3° valgus	Slight undercorrection	Slight undercorrection
Ligament release	Yes	Yes	No	Minimal	Minimal	Minimal	Minimal
Type	Systematic	Systematic	Patient specific	Hybrid	Hybrid	Hybrid	Hybrid

There have been many studies that compare KA and MA alignment techniques. Some studies have shown improved clinical outcomes in KA compared with MA at short-term follow-up, while others have shown no difference in clinical or functional outcomes between the two alignment techniques [22, 23, 24, 25]. Studies are very heterogeneous in the choice of the preoperative planning method, intraoperative alignment technique using jigs, 3D cutting blocks, patient-specific implants, or computer-assisted procedures.

The main concerns regarding KA are the varus or valgus outlier range of the tibial component and limb alignment that might adversely affect the long-term results. Some biomechanical studies showed that the varus position of the tibial component is associated with increased polyethylene wear, risk of varus collapse due to bone stress, and altered ligament strains as compared with the neutral aligned model [26]. However, in a retrospective review of 222 primary KA TKAs, Howell et al. showed that the aseptic revision rate at 10 years follow-up was 1.6%, with implant survivorship of 97.5%. Another critical point is the potential risk of patellofemoral instability due to the lack of external rotation of femoral component. However in a meta-analysis of 229 KA and 229 MA knees comparing the revision rate for patellofemoral complications, there was no difference between the two groups (1.3% vs. 1.3%) [27]. There is some merit to the use of more anatomic or patient-specific femoral components instead of standard implants designed and biomechanically tested for perpendicular stresses is reasonable [7].

iKA

With the advent of robotics, in 2022, Winnock de Grave described the iKA, which aims to resurface the prox- imal tibia ("true tibial resurfacing") with equal medial and lateral resections maintaining the native tibial joint line obliquity [9]. The main aim was to restrict the tibial extreme varus positioning that was a possibility with the KA. Then, the flexion and extension gaps are balanced by adjusting the femoral resections with no soft tissue or minimal releases [10]. The target was to restore the pre-arthritic medial proximal tibial angle (MPTA), remaining in a "restricted" safe zone of 84° (varus) to 92° (valgus) and the native coronal alignment within a HKA angle safe zone of 174–183°. There is no long-term data as yet.

rKA

In 2011, Vendittoli proposed the rKA protocol, setting boundaries to KA for patients with an outlier or atypical knee anatomy, to avoid excessive coronal deviation [10]. The first pillar of this protocol is to reproduce individual lower limb anatomy while keeping a HKA within ±3°. The second pillar is to reproduce the individual's anatomy keeping LDFA and MPTA within ±5°. Applying these rKA principles, 51% of the population would undergo a classic KA without any modification, another 30% would have a correction of <1°, and the remaining 20% of patients would require more substantial adjustments and slight ligament releases. As yet there are no mid-term or long-term studies for rKA.

aMA

aMA is an adaptation of classical MA with the aim to restore the pre-operative constitutional deformities with TKA. Implant position adjustment is made on femoral side while the tibial component is placed perpendicular to mechanical axis according to MA principles [12, 13]. This is a hybrid technique as the tibial component is systematically positioned at 90° and the femoral component is personalized according to the patient's anatomy [14, 15] within an accepted range up to 6° of residual varus or valgus deformity thus reducing the needed for ligament release. As yet there are no mid-term or long-term studies for aMA.

FA

This is an evolution of the KA method. The aim is to restore the natural obliquity of joint line and balance the knee flexion-extension gap by fine-tune adjustments of both the tibial and femoral components, avoiding soft-tissue releases [18]. Robotic technology is a prerequisite to assess implant position, resection thickness, joint gaps, and limb alignment during surgery. The femoral component in the coronal plane is inclined from a starting point of 0° to the mechanical axis to achieve the correct balancing between medial and lateral compartment. In the sagittal plane, the component is positioned to avoid femoral notching and to follow the natural bone's bowing. In the axial plane, the implant is aligned starting to the transepicondylar axis and moving ±3° to balance the flexion gap. On the other side, the tibial component is positioned to restore natural joint line inclination in coronal and sagittal plane avoiding valgus position [28]. Soft-tissue release must be considered only in case of severe fixed deformity.

Conclusion

Coronal alignment is considered a cornerstone to address the unresolved problem of patient dissatisfaction and the perception of an unnatural knee after TKA. This brief write up is meant to summarize each type of alignment with the underlying main principles and definitions. The coronal plane represents only one of the three-dimensional planes that could influence clinical outcomes. Sagittal and rotation alignment largely affect the postoperative kinematics and clinical results too. Abnormal internal or external rotational alignment of the tibial or femoral component leads to patellofemoral maltracking, and

abnormal ligament tension during knee flexion can cause unexplained painful TKA.

Another drawback of the current literature is the absence of a standard surgical technique for the same type of alignment, which makes clinical results not comparable to each other. The surgical technique is an adaptation of the conventional technique using mechanical jigs. However, studies have shown that using standard jigs-based techniques for alignment falls outside ±3° of the target in up to 30% of patients [29]. Therefore, the surgical technique could be considered an important bias that may influence results. In this sense, robotic surgery can help standardize the surgical technique and make bony resections and component alignment more reproducible to improve the comparability of clinical studies [28].

The conventional TKA components are designed to be implanted with the MA technique. With the evolution of newer alignment philosophies, it is reasonable to design implants to replicate the constitutional pre-arthritic knee anatomy [30].

In 2019, Hirschmann et al. introduced the concept that different functional knee phenotypes require an individualized approach to TKA coronal alignment. In 2021, MacDessi et al. published their coronal plane alignment of the knee classification that could help surgeons to determine which alignment strategy is best suited for each patient [31].

We may choose one of the above alignment philosophies in knees with mild varus. The idea of these philosophies is to let the patient "feel" his knee like the pre-arthritic knee with only bone cuts without much soft-tissue release. However, the success of these alternative philosophies is still not established for knees with varus deformities more than 20° as well as in patients with any kind of valgus deformity greater than 3°. For such cases, the literature is still almost all about the MA showing that post-operative neutral alignment results in longer TKA survival time than residual varus alignment [32].

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the Journal. The patient understands that his name and initials will not be published, and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

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