

Kinematically aligned total knee arthroplasty: alternative standardized technique?

Tomoyuki Matsumoto¹, Koji Takayama¹, Kazunari Ishida², Shinya Hayashi¹, Shingo Hashimoto¹, Ryosuke Kuroda¹

¹Department of Orthopaedic Surgery, Kobe University Graduate School of Medicine, Kobe, Japan; ²Department of Orthopaedic Surgery, Kobe Kaisei Hospital, Kobe, Japan

Correspondence to: Tomoyuki Matsumoto, MD. Department of Orthopaedic Surgery, Kobe University Graduate School of Medicine, 7-5-1, Kusunoki-cho, Chuo-ku, Kobe 650-0017, Japan. Email: matsun@m4.dion.ne.jp.

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Accurate osteotomy and implantation are important in total knee arthroplasty (TKA); misalignments have traditionally been reported to lead to early failure in TKA (1,2). Although the mechanical alignment method is traditionally recognized as the gold standard, kinematically aligned TKAs have recently gained a great interest for achieving better clinical outcomes (3,4). The primary goal of kinematically aligned TKA is to position the femoral and tibial components so that the angles and levels of the distal and posterior femoral joint lines and the tibial joint line are each restored to the patient's natural alignment, avoiding a neutral limb alignment unnatural to most patients (5,6). Kinematically aligned TKAs have been reported to replicate natural kinematics including medial pivot motion and bilateral femoral rollback (7,8). Several clinical studies have been published in support of kinematically aligned TKA. In a randomized controlled study at a two-year follow-up, Dossett *et al.* compared the clinical outcomes of patients undergoing either kinematically or mechanically aligned TKA and found better outcomes in the Western Ontario and McMaster Universities Arthritis Index (WOMAC), Oxford, Knee Society score (KSS), pain relief, and flexion angle in kinematically aligned TKA group (9). Howell *et al.* reported that kinematically aligned TKAs restored high function with the use of generic instruments as well as

patient specific instruments regardless of whether patients had an alignment categorized as an outlier or in-range (4,10). Nam *et al.* designed a multi-center study on a questionnaire to determine whether patients reported a normal knee or not after TKA and reported that patients with kinematically aligned TKA were three-times more likely to report having a normal knee than those with mechanically aligned TKA (11). With good clinical outcomes reported even at a mid-term follow-up (12), surgeons should know why this method is useful and safe, and carefully assess the long-term outcomes until this new technique becomes the standardized procedure for TKA.

There are several reasons except for the better clinical outcomes in kinematically compared to mechanically aligned TKA, including medial pivot motion and bilateral femoral rollback. There are two reported concepts supporting kinematically aligned TKA: joint line orientation to the floor and weight-bearing position in the knee joint. Hutt *et al.* and Ji *et al.* reported that the joint line orientation with respect to the floor while standing was almost parallel in patients who underwent kinematically aligned TKA, similar to young native knees (13,14). Similarly, Matsumoto *et al.* reported that the joint line orientation angle with double-leg standing was slightly varus in the kinematically and slightly valgus in the mechanically aligned TKA, and that

it changed to slightly valgus in the kinematically and more valgus in the mechanically aligned TKA in the single-leg standing condition (15). These findings indicate that after kinematically aligned TKAs, patients may be able to walk more naturally with the joint line being more parallel to the floor during the gait cycle than after mechanically aligned TKAs. The other rationale for better clinical outcomes in kinematically aligned TKA may be weight-bearing position in the knee joint after TKA, which influences long-term implant survivorship caused by polyethylene wear and prosthetic loosening. Haraguchi *et al.* recently suggested that the true mechanical axis should be assessed from the hip center to the lowest point of the calcaneus, and not the ankle center (16). Similarly, Mullaji *et al.* previously reported that the ground mechanical axis (line from the hip center to the ground reaction point) passes from the lateral to the center of the knee after mechanically aligned TKA, despite limb alignment being restored neutrally to the conventional mechanical axis (17). The assessment of the mechanical axis including the hind limb may change weight-bearing positions when compared to the assessment with the conventional mechanical axis, which may also be worth assessing with kinematically aligned TKA. Matsumoto *et al.* recently reported that the conventional mechanical axis passed through the slight medial position in the kinematically aligned TKAs and through the neutral position in the mechanically aligned TKAs. However, they also found that the line from the hip center to the bottom of the calcaneus (the true mechanical axis) (16) passed through the neutral position in the kinematically aligned TKA group, and the slight lateral position in the mechanically aligned TKA group (15). Though the usefulness of this new measurement method is unclear, these findings may remove the concern for early catastrophic failure in future kinematically aligned TKAs.

For kinematically aligned TKAs, concern for early catastrophic failure is often focused on the varus tibial bone cut. Although several papers have recently shown no difference in survivorship between aligned and out aligned TKAs (18,19), unexpected severe varus tibial implantations should be avoided as much as possible. Therefore, Matsumoto *et al.* recommend the use of navigation systems to avoid unexpected varus tibial osteotomy in kinematically aligned TKA (15). In addition, to avoid severe varus tibial implantation, they applied definitive 3 degree varus which was different from the previous reports (15), where tibial plateau inclination was about three degrees in asymptomatic volunteers regardless of age, but grew to

be about ten degrees with osteoarthritic progression (20). Recent reports of mechanically aligned TKAs for varus osteoarthritic patients by Vanlommel *et al.* showed superior clinical results with slight under correction of the limb (mild varus, $3^{\circ} < MA < 6^{\circ}$) to severe varus ($MA > 6^{\circ}$) and neutral ($MA \pm 3^{\circ}$) group (6). Similarly, Nishida *et al.* reported on 220 mechanically aligned TKAs in which postoperative severe varus and valgus alignment resulted in lower functional outcomes. However, postoperative mild varus as well as neutral mechanical alignment led to excellent clinical outcomes, suggesting surgeons should consider mild varus an acceptable outlier following postoperative limb alignment (21). In addition, Nakamura *et al.* recently reported on the bone model simulation study, stating that the moderate and severe varus model of kinematically aligned TKA showed higher contact force, stress, and bone strain at the medial side of the tibia when compared to those of normal and slight varus models of kinematically aligned TKA (8). Together, these findings suggest that severe varus tibial and limb alignment should be avoided when surgeons apply patients for kinematically aligned TKAs.

Kinematically aligned TKA has gained interest as a potential alternative for the traditional mechanical alignment method. However, recent reports regarding kinematically aligned TKA are still controversial. A recent randomized controlled trial by Waterson *et al.* reported no difference between 36 kinematically and 35 mechanically aligned TKAs in knee injury and osteoarthritis outcome score (KOOS), KSS, Short Form-36, Euro-Qol (EQ-5D), range of movement, two-minute walk, and timed up and go tests at one-year follow-up (22). Young *et al.* could also find no differences in Oxford Knee Score, WOMAC, and Forgotten Joint Score between 49 kinematically and 49 mechanically aligned TKAs after a two-year follow-up despite a tendency of better scores in kinematically aligned TKAs (23). However, Calliess *et al.* recently reported as a prospective randomized study that 100 kinematically aligned TKAs exhibited superior results in WOMAC and KSS to 100 mechanically aligned TKAs at a one-year follow-up (24). Similarly, Matsumoto *et al.* reported that 30 kinematically aligned TKAs resulted in better improvement of functional scores in 2011 KSS and flexion angles compared with 30 mechanically aligned TKAs at a one-year follow-up (15). However, they could find no differences in the other category other than functional score and flexion angle (objective knee indicator, patient expectations, patient satisfaction) between the two group (15). Kinematically aligned TKA is still under evaluation and larger studies are

needed to establish which alignment method will promote the best clinical outcome after TKA. The concept of restoring the normal or prearthritic status when performing a TKA may be valid for a large number of patients but may not for all patients. Although a final judgement regarding these alignment targets should wait for long-term results, there are other important factors including patient selection, soft tissue balance, and prosthesis design which influence clinical outcomes and patient satisfaction. Thus, surgeons should know that adjusting alignment is just one of the essential elements in TKA for improving patient outcomes and satisfaction.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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