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Kinematically Aligned Total Knee Arthroplasty or Mechanically Aligned Total Knee Arthroplasty

Abstract

Background: Kinematically aligned TKA (KATKA) was developed to more anatomically align the knee prosthesis to restore the native alignment of the knee and promote physiological kinematics. Even though there are concerns with implant survival and follow up at 10 years or more after KATKA has not been reported, there is a negligible incidence of failure of a tibial component at two to nine years. Early clinical results with this technique are encouraging and demonstrate better functional outcomes compared to mechanically alignment TKA (MATKA).

The purpose of this study is to perform a systematic review and meta-analysis of the literature to determine whether there are any clinical differences between KATKA and MATKA.

Methods: The authors conducted a systematic review of the English literature. Five randomized controlled trials which compared clinical outcomes of KATKA and MATKA were finally included. Four RCTs used patient specific instrument and, one

RCT used navigation. Data were extracted and meta-analysis was conducted.

Results: KATKA patients had better outcomes: Mean difference between KATKA and MATKA and p value are presented in brackets after each variable: WOMAC (-12.5; P<0.0001), OKS (2.3; P=0.030), C-KSS (13.1; P<0.0001), KFS (6.4; P=0.0070) and postoperative ROM (4.1°; P=0.0010). There was no significant difference concerning the complication rates which needed re-operations or revision surgery (Odds ratio, 1.01; P=0.99). KATKA components had a more femoral valgus (-1.8°; P<0.0001), more tibial varus (1.2°; P=0.0001), and more tibial slope (1.2°; P=0.0001), all being statistically significantly different.

Conclusions: Better clinical outcomes were obtained in KATKA and component placement in KATKA is significantly different from that in MATKA. There was no increase of patients with poor clinical results due to implant position especially for varus placement of tibial component. This systematic review of five RCTs suggests that KATKA is of potential alternative method to MATKA since the risk of revision for tibial loosening is negligible compared with MATKA for the same follow up period.

Keywords:

knee osteoarthritis; total knee arthroplasty; kinematically alignment; mechanically alignment; outcomes.

Introduction

Total knee arthroplasty (TKA) has been an established procedure for end stage arthritis of knee to improve function and alleviate pain. Modern designs, better surgical skills, better fixation technique and rehabilitation, have all contributed to better outcomes and longevity of implants. Around 90,000 primary TKAs were performed in the UK last year and numbers continue to increase year on year[1]. One of the prerequisites of a successful TKA is restoration of neutral knee alignment while placing the femur in external rotation to make the flexion gap symmetrical and match it with the extension gap. It requires that an initial femoral cut must be perpendicular to the mechanical axis of the femur and the tibial cut must be performed perpendicular to the mechanical axis of the tibia. Traditionally a mechanical axis alignment passing from the centre of femoral head to the centre of knee and the centre of ankle has been strived for. Mechanical alignment in TKA has been thought to be a functional principle because even load distribution is achieved and this is primarily to reduce wear and associated implant loosening[2-6]. However, native knee alignment, with proximal tibia is averaged

3°of varus and distal femur is averaged 3°of valgus with respect to its mechanical axis is different of that after TKA.

In spite of implant survival in excess of 90% at 10 years, international arthroplasty registries in the United Kingdom, Canada, and New Zealand have shown that up to 25% of patients with mechanically aligned TKA (MATKA) are dissatisfied, the causes of which remain poorly understood. Mechanical alignment can have unfavorable kinematic results as positioning of the components can change the level and angle of the distal femoral, posterior femoral, and tibial joint lines and lower limb alignment from normal[7] even though there is a wide individual variability in what is called 'normal limb alignment' and certain populations have "constitutional varus" [8-11]. When MATKA is performed for patients with constitutional varus knee, excessive soft tissue release and tibial bone resection may be required thus resulting in poor patient satisfaction.

Kinematically aligned TKA (KATKA) was developed in 2006 to more anatomically align the knee prosthesis to promote physiological kinematics which will help patients achieve better function and less pain with the belief that this will lead to reduce the incidence of instability, stiffness and improving the rate of recovery and kinematics thus improving patient satisfaction[12-15]. KATKA strives to restore normal knee function by aligning the angle and level of the distal femoral, posterior femoral, and tibial joint line to those of the normal knee[12,15]. Bone cuts are made to replace and resurface the native joint thus preserving the natural anatomy of the knee; this results in the alignment of the components with the three kinematic axes of the knee, maintains the soft tissue envelope, and minimizes the need for ligament release[8,13,16-18]. Early clinical results with this technique are encouraging and demonstrate better functional scores and range of motion compared to mechanical alignment.

One potential limitation of this method is the inability of the surgeons to consistently achieve the intended component position after implanting TKA. This can affect the operated limb significantly which may lead to poor function and place the components at a higher risk for catastrophic failure. However, as shown by Nedopil et al.[19] there really is very little inconsistency in cutting the tibial component in more than 3 degrees varus from the native contralateral limb. In addition, it is now known with two to nine year follow up of patients with KATKA that the risk of varus loosening is negligible and only 1/5 of that reported from MATKA[20,21].

One explanation for the negligible risk of varus tibia loosening after KATKA is that the in vivo forces in the medial and lateral hemi-joint are comparable to the native knee and the mean force in the medial and lateral compartments were three to six times lower than those of MATKA[22]. KATKA is growing in popularity with some randomized controlled trials (RCT) showing better outcomes[11,17,23,24]. On the other hand, other reported no particular advantage over MATKA. So there still remains controversy.

Currently, there is a paucity of comparative clinical data on the outcomes of KATKA to MATKA. The purpose of this study is to perform a systematic review and meta-analysis of the literature to determine whether there are any clinical differences in KATKA compared with traditional MATKA.

Material and methods

Search strategy and criteria

A comprehensive literature search of MEDLINE / PubMed electronic databases and CENTRAL / Cochrane Library for all articles written in English language was performed in October 2017. The included MESH terms were “total knee arthroplasty,” "osteoarthritis," "kinematic," "kinematically or kinematic alignment".

Inclusion criteria

Inclusion criteria for this systematic review were as follows; (1) English written articles, (2) full text of the article was available, (3) studies using human study, (4) studies about comparison between KATKA and MATKA, (5) articles about clinical and radiological outcomes. Exclusion criteria were; (1) articles not written in English, (2) full text was unavailable, (3) experimental study using animal or cadaveric specimen, (4) clinical study without clinical and radiological outcomes".

The citations were screened by all authors, titles and abstract were screened for relevance. After that, full texts of the selected articles were reviewed whether to be included in this systematic review. All extracted data were cross checked by all authors. Studies satisfying inclusion and exclusion criteria were independently reviewed by all authors. The search process to determine which studies were selected is detailed as a flow diagram (Fig. 1). The primary outcome measure of our interest was clinical outcome and secondary one was radiological evaluation. Six articles of RCT were included in the initial analysis [11,17,23-26]. One RCT was subsequently excluded because follow up period was only six months[17]. There were two level I[23,26], and three level II[11,24,25] studies in this systematic review to compare clinical outcome and radiological evaluations.

Analysis of data

Bias within studies was quantified using ‘Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines[27]. All analyses were performed and figures produced using Review Manager 5.3.3 (The Cochrane Collaboration, Oxford, UK).

Outcomes of search

Five studies were included in the systematic review and all were randomized, single-center, prospective cohort studies (Table. 1.). There are total of 518 cases of TKA: KATKA (n=259) and MATKA (n=259). Follow up periods were one year in three studies, and two years in two studies. KATKA and MATKA groups were well matched for age (mean difference, -0.8 years; 95% confidence interval, -2.4 to 0.7 years; P=0.29), and gender (Odds ratio, 1.21; 95% confidence interval, 0.80 to 1.85; P=0.36). Implanted prostheses were Vanguard (Zimmer Biomet, Inc, Warsaw, Indiana, USA) in one study, (e-motion, B. Braun Aesculap, Tuttlingen, Germany or Persona, Zimmer Biomet, Inc, Warsaw, Indiana, USA) in one study and Triathlon (Stryker, Inc, Mahwah, New Jersey, USA) in the other three studies. All prostheses were cemented and posterior cruciate ligament was retained in all the cases. Surgical approaches were medial para-patellar in three studies[11,25,26] and not described in the other two studies. Patella resurfacing was performed in two studies[23,25], selectively performed in one study[26] and not described in two studies[11,24]. Four procedures in KATKA group were performed using patient-specific guides made from MRI data and one using navigation[11] positioning in kinematic alignment. Pre and postoperative ROM were measured in all five studies.

Results

Clinical results

Were there any differences concerning preoperative conditions between KATKA and MATKA?

In the preoperative evaluations, we found no significant differences in any of the following criteris:

Range of motion (ROM) in both flexion (mean difference, 1.3°; 95% confidence interval, -2.0 to 4.5°; P=0.45) and extension (mean difference, 0.7°; 95% confidence interval, -0.5 to 1.8°; P=0.24), The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scale (mean difference, -3.1 points; 95% confidence interval, -6.6 to 0.5 points; P=0.093), Oxford Knee Score (OKS) (mean difference, 0.4 points; 95% confidence interval, -1.5 to 2.2 points; P=0.70), combined Knee Society Score (C-KSS) (mean difference, 5.2 points; 95% confidence interval, -3.4 to 13.7 points; P=0.23), Knee Society Score (KSS) (mean difference, 1.6 points; 95% confidence interval, -2.8 to 6.0 points; P=0.49), Knee Function Score (KFS) (mean difference, 1.1 points; 95% confidence interval, -3.5 to 5.8 points; P=0.63) and BMI (mean difference, -0.58 kg/m^2 points; 95% confidence interval, -1.38 to 0.23 kg/m^2 points; P =0.16).

Does KATKA achieve better clinical outcome compared with MATKA?

KATKA had a better WOMAC scale (mean difference, -12.5 points; 95% confidence interval, -16.1 to -9.0 points; P<0.0001), OKS (mean difference, 2.3 points; 95% confidence interval, 0.2 to 4.4 points; P=0.030), C-KSS (mean difference, 13.1 points; 95% confidence interval, 8.5 to 17.7 points; P<0.0001), KFS (mean difference, 6.4 points; 95% confidence interval, 1.7 to 11.0 points; P=0.0070) and postoperative ROM (mean difference, 4.1°; 95% confidence interval, 1.7 to 6.5°; P=0.0010). On the other hand, we found no significant difference concerning KSS (mean difference, 1.1 points; 95% confidence interval, -1.0 to 3.3 points; P=0.29), EuroQol five dimensions questionnaire (EQ-5D) (mean difference, -1.4 points; 95% confidence interval, -6.3 to 3.4 points; P=0.57), and length of hospital stay (mean difference, 1.0 days; 95% confidence interval, -0.2 to 2.2 days; P=0.092) between KATKA and MATKA (Fig. 2-6).

Does complication rate which needed multiple re-operations or revision surgery after KATKA differ from that after MATKA?

There was no significant difference in the reported complication rates including re-operations or revision surgery (Odds ratio, 1.01; 95% confidence interval, 0.25 to 4.09; P=0.99) between KATKA and MATKA (Fig. 7).

Radiological evaluations

Are there any differences concerning knee and component alignment KATKA and MATKA?

All five studies reported the radiological evaluations after KATKA and MATKA. KATKA had a more valgus angle between femoral component and femoral axis (mean difference, -1.8°; 95% confidence interval, -2.4 to -1.1°; P<0.0001), more varus angle between tibial component and tibial axis (mean difference, 1.2°; 95% confidence interval, 0.9 to -1.4°; P=0.0001), more tibial component slope to sagittal tibial axis (mean difference, 1.2°; 95% confidence interval, 0.6 to -1.7°; P=0.0001) (Fig. 8-10). On the other hand, we found no significant difference concerning valgus Hip Knee Angle (HKA) (mean difference, -0.4°; 95% confidence interval, -0.8 to 0.1°; P=0.087)

Discussion

The main findings of this systematic review were: (1) the clinical outcomes of KATKA were superior to those of MATKA in many clinical assessment questionnaires. (2) Limb alignment after KATKA was similar to that after MATKA however, component alignment was different between KA and MATKA. Femoral component was placed in more valgus and tibial component was placed in more varus in KATKA as compared to MATKA. (3) Complication rates were not significantly different between KA and MATKA.

KATKA was developed to reproduce normal knee kinematics after TKA. The concept of kinematic alignment has gained interest among knee surgeons[12,15,28,29]. Kinematic alignment has been popularised by Howell in the United States. The idea of kinematic alignment is not totally new. It is inspired indeed from the concept of anatomical alignment of Hungerford and Krackow[30]. It challenges the traditional alignment principles of restoring a 'normal' mechanical axis; using the transepicondylar axis as the flexion / extension axis, which in one report has been recognised to actually lie proximal and anterior to the transepicondylar axis[31]; externally rotating the femoral component and soft tissue balancing.

Knee kinematics after conventional MATKA is supposed to be different from normal because mechanical alignment can have unfavorable kinematic results as positioning of the components may change the level and angle of the distal femoral, posterior femoral, and tibial joint lines and lower limb alignment from normal. Joint line changes from normal alter the knee kinematics because the normal joint lines are either parallel or perpendicular to the three axes that describe tibiofemoral and patella femoral kinematics[8-11,29,32]. And there are many patients whose knees are in "constitutional varus". Substantial number of native limbs do not have a neutral HKA angle prior to the onset of osteoarthritis[28,33-35]. There is a 7° to 12° range of maximum varus and the -4° to -16° range of maximum valgus reported for subjects in Korea, India, and Belgium. 17% to 35% of adults have constitutional varus and the 0% to 12% have constitutional valgus reported for subjects from Korea, India, and Belgium. Hence, patients from different countries often have a pre-arthritic HKA angle outside 0° ± 3°, and constitutional varus is more frequent than constitutional valgus. So KATKA may be beneficial alternative to

MATKA was for the patients with constitutional varus to avoid excessive soft tissue release and bone resection to obtain symmetrical extension and flexion gap. There still remains concern about longevity of component placement which is not placed perpendicular to mechanical axis of femur and tibia, especially for tibial component placement, varus placement more than 3° may increase the risk of early loosening. However, there are two to nine year follow up studies from several authors showing negligible risk of varus loosening, five times lower than that reported for mechanically aligned TKA[21]. The etiology of this is proposed to be due to the lower medial and lateral forces compared to mechanically aligned TKA[22]. Parratte et al. showed that postoperative mechanical axis of $0^0 \pm 3^0$ did not improve the fifteen-year implant survival rate. Eckhoff et al.[28] have shown that 98% of normal limbs do not have a neutral mechanical axis, and that 76% of normal limbs have a deviation of >3° from neutral. Bellemans et al.[29] have shown that 32% of men and 17% of women had constitutional varus knees with a natural mechanical alignment of more than 3°[30]. Because of the great variations in limb alignment and the fact that 98% of normal limbs do not have a neutral limb alignment, the correction of the arthritic knee to a neutral mechanical axis does not represent a correction to normal[28,29].

There are some limitations to this study. Firstly, surgical technique such as approach technique and implant selection was not consistent in five RCTs. However, all procedures in KATKA group were performed using patient-specific guides made from MRI data or navigation positioning in kinematic alignment to minimize the technical variations and inaccurate component placement. Secondly, the follow up periods of included RCTs were one year or two years. Ideally, multicenter RCT with longer follow up period are needed to clarify the definitive difference between two procedures in particular the issue of increased wear. Thirdly, we could not clarify the relationship between preoperative patient conditions and postoperative clinical outcomes from this study. Further studies are required to clarify the effect of preoperative limb deformity to the postoperative outcomes both after KATKA and MATKA.

It is important that future studies provide these answers, have adequate sample size and a meaningful follow up to understand the actual potential of KATKA.

Conclusions

Better clinical outcomes were obtained in KATKA and component placement in KATKA is significantly different from that in MATKA. Even though follow up periods were short, there was no increase of patients with poor clinical results due to implant position especially for varus placement of tibial component.

This systematic review of five RCTs suggests that KATKA is of potential alternative method to MATKA. However, RCT with longer follow up period will be required to clarify its longevity.

List of abbreviations:

C-KSS: Combined Knee Society Score

EQ-5D: EuroQol five dimensions questionnaire

KA: Kinematically Aligned

KFS: Knee Function Score

KSS: Knee Society Score

MA: Mechanically Aligned

PRISMA: Preferred Reporting Items for Systematic reviews and Meta-Analyses

RCT: Randomized Controlled Trial

ROM: Range Of Motion

TKA: Total Knee Arthroplasty

WOMAC: The Western Ontario and McMaster Universities Osteoarthritis Index

Conflict of interest

The authors have no financial conflict of interest in this study.

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Ethical approval

This is a systematic review so ethical approval was waived.

Written informed consent

Not applicable.

Contribution of authors

TT, JA, and HP designed the study, conducted literature search, systematic review of the literature, and statistical analysis. All authors read and approved the final manuscript.

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Figure captions

Figure 1. PRISMA flow diagram

Figure 2. Forest plot for postoperative WOMAC between KA (Experimental) and MA (Control) TKA

Figure 3. Forest plot for postoperative OKS between KA (Experimental) and MA (Control) TKA

Figure 4. Forest plot for postoperative Combined KSS between KA (Experimental) and MA (Control) TKA

Figure 5. Forest plot for postoperative KFS between KA (Experimental) and MA (Control) TKA

Figure 6. Forest plot for postoperative ROM between KA (Experimental) and MA (Control) TKA

Figure 7. Forest plot for major complications between KA (Experimental) and MA

(Control) TKA

Figure 8. Forest plot for angle of femoral component between KA (Experimental) and MA (Control) TKA

Figure 9. Forest plot for angle of tibial component between KA (Experimental) and MA (Control) TKA

Figure 10. Forest plot for tibial component slope between KA (Experimental) and MA (Control) TKA