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RESEARCH ARTICLE

Anatomic *Versus* Mechanically Aligned Total Knee Arthroplasty for Unicompartmental Knee Arthroplasty Revision

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Abstract:

Objectives:

The purpose of this study was to compare the intra-operative benefits and the clinical outcomes from kinematic or mechanical alignment for total knee arthroplasty (TKA) in patients undergoing revision of failed unicompartmental kneel arthroplasty (UKA) to TKA.

Methods:

Ten revisions were performed with a kinematic alignment technique and 11 with a mechanical alignment. Measurements of the hip-knee-ankle angle (HKA), the lateral distal femoral angle (LDFA), and the medial proximal tibial angle (MPTA) were performed using long-leg radiographs. The need for augments, stems, and constrained inserts was compared between groups. Clinical outcomes were compared using the WOMAC score along with maximum distance walked as well as knee range of motion obtained prior to discharge. All data was obtained by a retrospective review of patient files.

Results:

The kinematic group required less augments, stems, and constrained inserts than the mechanical group and thinner polyethylene bearings. There were significant differences in the lateral distal femoral angle (LDFA) and the medial proximal tibial angle (MPTA) between the two groups (p<0.05). The mean WOMAC score obtained at discharge was better in the kinematic group as was mean knee flexion. At last follow up of 34 months for the kinematic group and 58 months for the mechanical group, no orthopedic complications or reoperations were recorded.

Conclusion:

Although this study has a small patient cohort, our results suggest that kinematic alignment for TKA after UKA revision is an attractive method. Further studies are warranted.

Keywords: Kinematic alignment, Mechanical alignment, Osteoarthritis revision surgery, Total knee arthroplasty, Unicompartmental knee revision.

INTRODUCTION

Unicompartmental knee arthroplasty (UKA) has been associated with higher revision rates than total knee arthroplasty (TKA) [1]. Currently, when UKA fails, the usual procedure is revision to primary TKA. The outcomes of

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revision have, however, been shown to be less optimal than primary TKA [2]. Furthermore, following revision, the need for metallic augments and for supplementing fixation with stems is common [3].

In TKA, the usual practice is to perpendicularly align the implants to the femoral and tibial mechanical axes, thus recreating a neutral hip-knee-ankle angle (HKA); this practice is referred to as mechanical alignment [4]. Recently, anatomic alignment has been proposed as an alternative option to mechanical alignment [5 - 7]. Here, bone cuts are made in order 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 [4, 8 - 10]. Early clinical results with this technique are encouraging and demonstrate improved functional scores and better range of motion compared to mechanical alignment [8, 11].

To our knowledge, no studies have been published that compare mechanical and kinematic alignment of TKA when performed for revision of failed UKA. The purpose of this study was to, therefore, compare mechanical and kinematic alignment using computer navigation for medial UKA revision. The primary objective was to determine the intra operative benefits of kinematic alignment by comparing the uses of metallic augment, supplemental stems, and constrained implants between the two groups. Secondary objectives included comparing the post-operative radiographic measurements in both groups as well as the clinical outcomes measured with the Western Ontario and McMaster Universities Arthritis Index (WOMAC) scores [12, 13], the distance walked prior to discharge from the hospital as well as the maximum active flexion and extension obtained at discharge.

MATERIALS AND METHODS

This was a retrospective study of all patients who had undergone medial UKA revision between 2006 and august 2014 by the senior author (PAV). This study was approved by the hospital research committee and informed consent was obtained. Patients were identified from our arthroplasty database. Patients revised for infection or failed lateral UKA were excluded. The creation of two groups (kinematic and mechanic) was possible due to a change in practice: before March 2011, all TKA were performed using mechanical alignment, and kinematic alignment was introduced afterwards.

Patient demographics, body mass index (BMI), use of augment spacers, stems, types of implant constraints, furthest distance walked prior to discharge as well as maximum flexion and extension prior to discharge were obtained from patient charts and recorded. In order to assess clinical outcomes, the WOMAC questionnaire was administered to all patients via telephone by one investigator (PT).

Patient Characteristics

Twenty-five patients who had undergone revision UKA were identified in our database. Four were excluded: two underwent revision for infection and two had a failed lateral UKA. This left 11 subjects with mechanically aligned TKA and 10 with kinematically aligned revision TKA. Table **1** presents selected patients' characteristics. Subjects in the mechanical group had a mean age of 66 years (SD: 13.1, range: 49 to 92 years) and subjects in the kinematic alignment group had a mean age of 64 (SD: 8.2, range: 56 to 79 years). Forty-five percent of patients in the mechanical group (5/11) were male compared to 30% of patients in the kinematic group (3/10). The mean body mass indexes (BMI) were 29.5 (SD: 8.9, range 17.2 to 45.3) and 31.7 (SD: 7.6, range 22.7 to 41.7) in the mechanical and kinematic groups respectively. Osteoarthritis progression was the primary reason for revision in both groups followed by aseptic loosening of the implant.

Surgical Techniques

All patients received a fixed bearing implant (Triathlon, Stryker, Mawaw, US). The surgical approach was an anterolateral skin incision with a standard medial parapatellar arthrotomy. No tourniquet was used. Kinematic alignment in the coronal plane was achieved using optical computer navigation (Orthomap ASM, Stryker, Michigan, US). The position of the hip centre, femoral centre and axis, tibial centre and axis and malleoli were recorded. After femoral and tibial implant removal, the distal femoral and proximal tibial bony surfaces were mapped, and a navigated cutting jigsaw was used to make the distal femoral and proximal tibial resection.

Table 1. Baseline demographics and clinical characteristics.

	Mechanical alignment n=11	Kinematic alignment n=10
Mean age, years (SD)	66 (13)	64 (8)

(Table 1) contd.....

	Mechanical alignment n=11	Kinematic alignment n=10
Males, nb (%)	5 (45)	3 (30)
Mean BMI, kg/m^2 (SD)	29.5 (8.9)❖	31.7 (7.6)❖
Reasons for UKA revision	4	0
aseptic loosening	4	6
arthritis progression	1	3
trauma	1	
wear and tear	1	
bleeding		1
reaction to foreign body		

❖n=9

In the mechanical group, the cuts were adjusted to ensure a 9 mm resection on the lateral femoral condyle and tibial plateau (minimal implant thickness). Resection angles were then adjusted to 0 degrees according to the mechanical axis of femur and tibia. In the case where medial resection was -3 mm to -1 mm (no bone resected), we increased the lateral resection to obtain a 1 mm resection medially and increased polyethylene thickness. When resection was ≥ -4mm, we kept lateral resection to 9 mm, increased medial resection to 5 mm and used a 5 mm medial metallic augment. Femoral rotation was set according to the epicondylar axis. Medial ligament release was performed if needed and knee stability assessed to determine the need for constrained inserts.

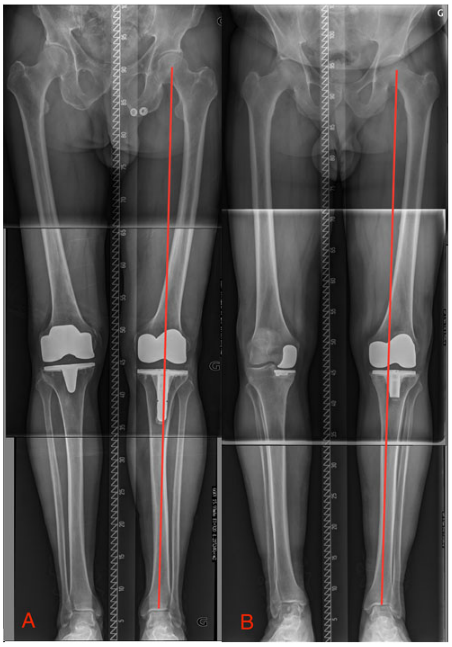

Fig. (1). Post-operative weight-bearing long-leg AP radiographs of a mechanically aligned TKA [**A**] and of a kinematically aligned TKA [**B**]. The line connecting the center of the femoral head and the ankle passes through the center of the knee in the mechanically aligned knee but not in the kinematic.

In the kinematic group, regardless of pre-operative deformity, only the deep medial collateral ligament was routinely released. The cuts were adjusted to ensure a 9 mm resection on the lateral femoral condyle and tibial plateau. Resection angles were then adjusted to compensate medial femoral condyle and tibial plateau cartilage and bone loss thicknesses, thus recreating the patient's native joint orientation. Because of the UKA implant thickness (femur 4 mm, tibia 8 mm), in most cases, bone resection on the medial surfaces was between 1-4 mm maximum. Resections angles were modified only if the measured angles fell outside a pre-defined safe range of either a combined coronal orientation within +/-3 degrees of neutral and/or independent femoral or tibial cuts within +/- 5 degrees. The femoral components were placed in neutral rotation according to the posterior condyles compensating with a 4 mm spacer on the medial side (UKA femoral implant thickness = 4 mm).

Radiographic measurements were made on post-operative weight-bearing long-leg AP radiographs by one investigator (MAL). The mechanical axis of the femur was defined as a line connecting the center of the femoral head to the center of the knee. The mechanical axis of the tibia was defined as a line connecting the center of the knee and the center of the talus. The anatomic axis of the femur and the anatomic axis of the tibia were respectively defined as lines drawn along the length of the intramedullary canals of the femur and the tibia. The following angles were measured on the weight-bearing long-leg AP radiographs: the hip-knee-ankle (HKA) angle, the medial proximal tibial angle (MPTA) and the lateral distal femoral angle (LDFA). Fig. (**1**) shows sample weight-bearing long-leg AP radiographs of both anatomic and mechanical alignment.

Statistical Analysis

Descriptive statistics were used to summarize the patients' characteristics. The arithmetic mean, standard deviation (SD), and range were determined for each measure in the anatomic and kinematic groups. The differences in the means were calculated using the Wilcoxon signed-rank test. Significance was set at α=0.05. All calculations were made using SPSS version 19.0 (Armonk, NY: IBM Corp.).

RESULTS

Surgical Procedure and Types of Implants

In the kinematically aligned group, 1/10 (10%) of patients required a 5 mm tibial augment spacers compared to 3/11 (28%) of patients in the mechanical group. No supplemental tibial stems were needed in the kinematic group whereas 3 were required in the mechanical group. In the kinematic group, mean polyethylene thickness was 9.6 mm (SD: 1.0, range: 9 to 11) *vs*. 10.7 mm (SD: 1.6, range: 9 to 14) in the mechanic group (*p*=0.8). Constrained implants were not required in either group.

Radiographic Measurements

Radiographic measurements are presented in Table **2**. The mean HKA was 1.3° in varus in the kinematic group (SD: 1.7, range: 3.3° varus to 1.2° valgus) *vs*. 1.7° in varus in the mechanical group (SD 1.8, range: 6.0° varus to 0.4 valgus) (*p*=0.87). In the kinematically aligned group, the mean MPTA was 2.4° in varus in the kinematic group (SD: 1.9, range: 5.0° varus to 0.3° valgus) *versus* 0.8° in varus in the mechanical group (SD: 1.7, range: 5.2° varus to 1.2° valgus) (*p*=0.04). The LDFA was 1.0° in valgus in the kinematic group (SD, 1.8, range: 1.6° varus to 4.0° valgus) compared to 1.3° in varus in the mechanical group (SD: 1.0, range: 2.7° varus to 0.4° valgus) (*p*=0.01).

Table 2. Radiographic measurements.

	Mechanical alignment n=11	Kinematic alignment n=10	*p*-value
HKA	1.7⌘	1.3❖	0.87
MPTA	0.8[§]	2.4	0.04
LDFA	1.3⌘	-1.0❖	0.01

[a] + varus/- valgus, ⌘ n=7, ❖n=9, [§] n=10

Clinical Outcomes

At last follow up of 34 months for the kinematic group and 58 months for the mechanical group, no orthopedic complications or reoperations were recorded. Clinical outcomes measures are presented in Table **3**. At last follow up, the mean WOMAC score was 13 points better in the kinematic group: 8.8 (SD: 15.5, range: 0-46) *versus* 22.3 (SD: 29.9, range: 0-87) (*p*=0.49). In the kinematic group, the patients walked an average of 35.6 meters (SD: 29.1, range: 10-100 m) *versus* 30.2 meters (SD: 15.0, range: 12-60 m) in the mechanical group (*p*= 0.96). In the kinematic group, prior to discharge, a mean flexion of 95° (SD: 12°, range: 70-110°) was attained compared to 83° (SD: 8°, range: 65-90°) in the mechanical group (*p*=0.01). In the kinematic group, the lowest flexion value (70°) was found in a patient who underwent revision following trauma and in the remaining patients, the values ranged from 90° to 110°. In the mechanical group, the lowest flexion value (65°) was found in a patient who underwent revision following arthritis progression and, in the remaining patients, the range was between 80°-90° for flexion. Eighty-eight percent (7/8) patients in the kinematic group managed to completely extend their knee (defined as an extension of 0°) compared to 50% (4/8) in the mechanical group.

Table 3. Surgical procedure, clinical outcome scores, and movement prior to discharge.

	Mechanical alignment n=11	Kinematic alignment n=10	*p*-value
Womac score, mean	22.3	8.8	0.49
Time at WOMAC, months (SD)	58 (30)⌘	34 (29)[§]	---
Post-operative motion			
mean flexion, ° (SD)	83° (8)[§]	95° (12)[§]	0.01
complete extension (%)	4 (50) [§]	7 (88) [§]	---
Distance walked prior to discharge, m (SD)	30.2 (15.0)	35.6 (29.1)	0.96
Augment spacers, nb (%)	3 (28)	1 (10)	---
Tibial stems, nb (%)	3 (28)	0 (0)	---
Polyethylene thickness, mean (SD)	10.7 (1.6)	9.6 (1.0)	0.8

[§]n=8, ⌘ n=7

DISCUSSION

Revision of UKA to TKA can often be a complex procedure since bony landmarks may be lost and patients may present with bony defects, thus rendering reconstruction difficult [14]. Stems and augments are sometimes required to improve fixation and constrained inserts may be necessary in cases of unsatisfactory ligament balance. Clinical results of UKA revision are known to be inferior to a primary TKA [2]. We hypothesized that using kinematic alignment during UKA revision would facilitate surgery and improve patient outcomes. Comparing a group of mechanically and kinematically aligned UKA revisions, we showed that the kinematically aligned group required less augment spacers, less tibial stems and overall, thinner polyethylene inserts than the mechanical group. In terms of clinical outcomes, the mean total WOMAC, knee flexion, and extension attained before discharge from the hospital were better in the kinematic group.

The major limitation of our work is the small number of patients in each group and, as such, our results should be interpreted with caution and should be reconfirmed with larger trials. While our center is an arthroplasty center, only 25 patients had undergone revision UKA in the last eight years. A multicenter study would have been more ideal in terms of ensuring larger cohort numbers and would have allowed the inclusion of patients who had undergone revision TKA by more than one surgeon. By only including patients that were operated on by one surgeon, we may be limiting the extent to which our findings can be generalized.

Furthermore, because of the limited number of patients, our study power is small and thus, we are unable to detect small differences between the two groups. It therefore remains possible that certain differences that we have deemed non-statistically significant are, in fact, statistically significant and clinically important. In terms of what we have established as being statistically significant, it also remains possible that the differences between the two groups are larger than what we are reporting. Also, the clinical significance of the results in our study is primarily inferred by the WOMAC and, even though this is a validated tool, more data points are needed to fully conclude on clinical significance. This study was retrospective and we acknowledge that a randomized controlled trial would have been the gold standard in terms of determining differences between the groups.

The most common practice for alignment in TKA is to create a neutral lower limb axis by cutting distal femoral and proximal tibial bone at 90 degrees to their respective mechanical axes, with the femoral component placed in external rotation to achieve ligament balance in flexion: this is the standard mechanical alignment technique [4]. TKAs implanted in this manner have established long term survivorship [15]. The disadvantage of this method is that it alters joint line orientation when compared with many patients' native anatomy. Kinematic alignment is an alternative option [5 - 7]. Bone cuts are made to replace and resurface the native joint, preserving the natural anatomy of the knee. For most UKA, surgical technique aims at resurfacing the medial compartment while restoring the lower limb alignment to its pre arthritic stage, often leaving a little of varus which protects the lateral compartment. With the current implants designs, due to implant thickness, bone resections are often thicker than when performing a mechanically aligned TKA. Adding the bone loss associated with UKA loosening, a medial bone defect is often present when performing UKA revision with a mechanically aligned TKA [3].

In our study, using a kinematic technique, our tibial cuts were performed with some varus (mean MPTA of 2.4° in varus (range: 5.0° varus to 0.3° valgus). Such angles helped us to minimize the medial bone defect and the lateral plateau cut thickness and also reduced the need for an augment and the final polyethylene thickness used. This negated the need for a supplemental tibial stem in our kinematic group. On the femoral side, in most cases, bone defects were minimal irrespective of the technique used and thus, no augments or stems were required.

With respect to patient function and satisfaction, historically, mechanically aligned TKA has been shown to improve the quality of life of patients with end-stage knee arthritis yet recent data suggests that, following TKA, only 82% to 89% of patients are satisfied with the outcomes of the procedure [16 - 18]. Patient satisfaction with kinematic alignment, as evidenced by patient-reported function, is high and this perhaps because kinematic alignment avoids undesirable kinematic consequences by preserving knee joint anatomy, orientation and lower limb alignment [9]. Although our study was not powered to compare patient function on a validated scale, we found much better results on the WOMAC scale in our kinematic group: 9 *versus* 22 (*p*=0.49). Our WOMAC results are comparable to the only randomized study comparing kinematic and mechanical alignment in patients undergoing primary TKA in which Dossett *et al*. demonstrated that patients in the kinematically aligned group had significantly better WOMAC scores (15 *vs*. 26, *p*=0.005) [11]. Similarly to our findings, Dossett *et al*. also demonstrated significantly better flexion prior to discharge in the kinematic group (121° *vs*. 113°, *p*=0.002).

CONCLUSION

This study shows that kinematic alignment is suitable in UKA revision surgery and presents with certain advantages. Larger studies are warranted to further investigate the benefits of kinematic *versus* mechanical alignment for UKA revision.

LIST OF ABBREVIATIONS

BMI	=	Body mass index
HKA	=	Hip-knee-ankle angle
LDFA	=	The lateral distal femoral angle
MPTA	=	Medial proximal tibial angle
SD	=	Standard deviation
TKA	=	Total knee arthroplasty
UKA	=	Unicompartmental knee arthroplasty
WOMAC	=	Western Ontario and McMaster Universities Arthritis Index

CONFLICT OF INTEREST

Dr. Vendittoli and Dr. Lavigne are paid consultants for Microport and Stryker and receive research funding from Medacta, Microport, Stryker, Smith and Nephew, and Zimmer. The remaining authors have no conflicts of interest and we confirm that the contents of this article have no conflict of interest.

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