ACCURACY OF IMAGE-FREE COMPUTER NAVIGATED TOTAL KNEE ARTHROPLASTY IS NOT COMPROMISED IN SEVERELY DEFORMED VARUS KNEES

Abstract

In severe varus knee deformity, image-free computer navigated total knee arthroplasty (TKA) may result in a malaligned knee. The aim of this study was to compare the results of 17 severe varus knees (≥20°) and 81 varus knees (<20°) that underwent image-free computer navigated TKA and analyze postoperative malalignment. Computer navigated TKA was performed according to standard protocol, and component angles and mechanical axes were evaluated postoperatively with weight bearing full-length standing radiographs. All severe varus knees were corrected to within 3° of neutral lower limb alignment despite having a mean preoperative varus deformities of 22.4°. Neutral alignment was obtained in 88.9% of the varus group (mean preoperative varus deformity of 11.7°), without significant difference between the two groups. No significant difference was found in either the femoral or tibial component angles, or in the frequency of complications. Severity of varus deformity did not affect the accuracy of image-free computer navigated TKA.

Introduction

Large varus deformities may be predisposing factors to suboptimal component alignment by conventional total knee arthroplasty (TKA) and there are suggestions that it is difficult to correctly align severe knee deformities with computer navigated TKA [1-3]. The success of total knee arthroplasty is determined by accurate component placement and prosthetic knee component placement within 3° varus/valgus of the mechanical axis (MA) is important since it reduces the risk of early aseptic loosening and component failure [4-8]. While some recent literature has questioned the importance of postoperative alignment in TKA longevity, generally the alignment goals of TKA is to provide a neutral mechanical axis [9-11]. Computer-assisted navigation in joint surgery has been developed to increase accuracy of component placement and lower limb alignment and improve postoperative survival rates of implants. Introduction of computer-assisted navigation in total knee arthroplasty (TKA) has reduced bone-cutting and soft tissue release errors to improve lower limb alignment to achieve good long-term outcomes [12-14]. However, whether component placement accuracy and lower limb alignment is compromised by the degree of knee deformity with image-free computer navigated TKA has not been established. The purpose of this study was to assess the accuracy of image-free computer navigated TKA in varus and severe varus knees by comparing postoperative component alignment and lower limb alignment results in patients undergoing TKA. We hypothesized that there is no difference in component alignment and mechanical axes between varus and severe varus knees in these patients after surgery.

Materials and Methods

Between 2008 and 2009, 112 primary TKAs were performed at two institutions. Of these, 108 knees had preoperative varus alignment and underwent TKA using an image-free computer navigation system (OrthoPilot™ software version 4.2, B.Braun Aesculap, Tuttlingen, Germany). Six knees were excluded for lack of high quality full length standing preoperative and postoperative radiographs. Four knees were excluded for less than 2 years of clinical follow up. This left 98 knees, consisting of 65 women and nine men with a mean age of 74.1 years (range 54-82 years) available for review (Table 1). Exclusion criteria were knee joint deformity due to rheumatoid arthritis, valgus OA of the knee, patients with severe restriction in the range of motion of the hip, and history of TKA revision surgery.

For determining the severity of knee deformity, degree of varus deformity was calculated by examining lower limb alignment in the coronal plane on full-length weight bearing standing radiographs preoperatively (Fig 1A,B), then categorized into two groups. The degree of knee deformity was obtained by measuring the acute angle between the femoral mechanical axis and the tibial mechanical axis. The mechanical axis of the femur was defined as the line connecting the center of the femoral head to the highest point of the intracondylar notch. The tibial axis was defined as the line connecting the midpoint of the tibial spines to the center of the tibial plafond [15]. The severe varus group (SV group) was defined as having greater than or equal to 20° of varus deformity while varus knee group (V group) was defined as having less than 20° of varus deformity. The mean varus deformity for the SV group was 22.4°±2.0° (range 20°-27°), and 11.7°±4.5° (range 1°-19°) for the V group.

All TKAs were performed with the same computer navigated system under the supervision of one of two senior surgeons (Y.I. and H.O.), both with extensive experience in both conventional TKA and computer navigated TKA. All components in this study were implanted with e.motion or Columbus Total Knee System (B.Braun Aesculap, Tuttlingen, Germany) using OrthoPilot™ ver. 4.2 software (B.Braun Aesculap, Tuttlingen, Germany). A total of 97 TKA implants of cruciate retaining design were used versus one posterior stabilizing design, implanted due to PCL in sufficiency in this patient.

Image-free computer navigated TKA was performed according to standard protocol. A medial parapatellar approach was performed to expose the knee. After knee joint exposure, tracker diodes were positioned and fixed to the proximal tibia and distal femur. After registration of kinematics data, anatomical landmarks were registered, followed by ACL and menisci removal. The tibia cutting block was positioned on the tibia with a varus/valgus and anterior/posterior slope of 0°. The tibia was cut perpendicularly to the tibial mechanical axis and the navigation computer confirmed that alignment did not change significantly. All bone spurs of the distal medial and lateral femur and the proximal medial tibia were removed.

With the knee at full extension, the medial soft tissues of the knee were released first, then the overall soft tissues balance was adjusted and measured for straight alignment. The medial and lateral sides of the distractor (Distraction clamp, B.Braun Aesculap, Tuttlingen, Germany) were separated at equal forces. The gap distance was then analyzed with the navigation computer. When there was a discrepancy between the gaps at extension and flexion, some looseness of the joint at flexion was permitted. However, while the lateral side was allowed some leeway, the medial side was made to be tight. Release of medial soft tissues was performed based on the procedure described by Clayton et al [16]. First, the deep layer of the medial collateral ligament (MCL) was released, removing any ostephytes from the medial tibia and femur as required. Second, the superficial MCL was released, followed by the gradual release of the tibial insertion of the semimembranosus if required. Third, the pes anserine tendons were detached from the tibia if medial tightness further remained. This procedure was performed gradually such that the medial and lateral gap difference was less than 3 mm at both full extension and 90° flexion [17,18]. The amount of femoral cut was determined by adjusting the femoral component size, rotation angle, and the insert size such that the joint gap was rectangular at extension and flexion.

Rotational alignment of the tibial plateau was corrected using ventral marking. Internal rotation was avoided in all cases. Tibial and femoral trial implants were used to check component angles and lower limb alignments in flexion and extension before final component implantation. None of our patients required bone augmentation during surgery.

Postoperatively, femoral component angle (FCA), tibial component angle (TCA), and MA were examined on weight bearing full-length standing radiographs (Fig 1C,D). FCA was defined as the angle between a line drawn from the center of the femoral head to the center of the component and a line drawn across the femoral condyles in standing coronal plane radiographs. TCA was defined as the angle between a line drawn from the center of the ankle mortise to the center of the component and a line drawn across the tibial component surface. The mechanical axis in this study was defined as 180° subtracted from the sum of FCA and TCA (MA=FCA+TCA-180°). A positive value indicated varus angle, while a negative value indicated a valgus angle.

Statistical analysis was performed using the SPSS package for Windows version 12.0 (IBM SPSS, Tokyo, Japan). The arithmetic mean, standard deviation, and distribution were determined for each measure for the two groups. Shapiro-Wilk test was first performed to ensure a normal distribution of data. The Mann-Whitney U test was then used to compare data of the V and SV groups, with p values less than 0.05 being statistically significant. Significant difference of postoperative complications between V and SV groups was calculated using Pearson's χ^2 test.

Results

The SV group consisted of 17 knees (15 female knees, two male knees, mean age of 75.9±4.1 years) and the V group consisted of 81 knees (72 female knees, nine male knees, mean age of 73.4±5.4 years) (Table 2). BMI as a factor for indication of surgical complexity and difficulty was not significantly different between the two groups (p=0.22). Average FCA for the SV group was 90.8°±1.3° while the V group was 90.8°±2.0°, and difference between the groups was not significant (p=0.77, Fig 2). There were two outliers at 4° varus and 4° valgus in the V group. Average TCA for the SV group was 90.2°±1.1° while the V group was 90.3°±1.3°, and difference between the groups was not significant (p=0.84, Fig 3). One outlier was observed at 4° varus in the V group. MA within 3° of neutral lower limb alignment in the SV group was 100% with all 17 knees and the V group was 88.9% with 72 (Fig 4). There were nine outliers, seven at 4° and two at 5° varus angles.

For postoperative complications, we looked for surgical site infection, component loosening, component failure, and varus/valgus stress instability. With a minimum of two years of follow-up period, there were three complications for the V group but no complications for the SV group. Complications for the V group included one case of superficial dermal infection around the operated knee at three months, two cases of mediolateral instability at 22 and 30 months (both less than 10°) postoperatively. Pearson's χ^2 test indicated that these complications occurred by chance alone (p=0.65) and that there is no significant difference in the occurrence of complications between SV and V groups when undergoing computer navigated TKA.

Discussion

This study focused on the magnitude of preoperative varus alignment on the efficacy of image-free computer navigated TKA, with particular emphasis on severe varus deformity greater than or equal to 20°. In this series of 98 computer navigated TKA cases, all severe varus knees were corrected to within 3° of MA despite having average preoperative varus deformities of 22.4° (standard deviation of 2.0), which may lead to longer implant longevity and better patient outcomes. The degree of preoperative varus deformity did not affect component placement and MA in TKA performed with image-free computer navigation.

Improved component placement in varus knees through computer navigated surgery has been verified previously by other authors and better radiographic results were obtained in computer-assisted TKA than with conventional surgery techniques [19-23]. Obtaining neutral MA in TKA is more difficult in patients with large knee angle deformities because it requires extensive soft tissue balancing. However, our results suggest that image-free computer navigated TKA can facilitate tissue balancing and component placement to attain neutral alignment in severe varus knees if step-by-step soft tissue release and navigation procedures are carefully followed. Proper identification of landmarks and their registration, and accurate soft tissue balancing is mandatory for appropriate component placement and limb alignment [24]. Image-free computer navigated TKA registers anatomical landmarks and kinematics data to apply an algorithm to decide the center of joint motion and lower limb alignment for more accurate MA identification [7]. With image-free computed navigation, it is relatively easy to correct lower limb alignment without being influenced by local bone morphology as well as being able to perform soft tissue balancing during flexion and extension positions of the knee. Furthermore, expensive imaging and time consuming preoperative planning is not required, cutting both cost and time compared to other computer navigated techniques [24].

Some recently published studies question the importance of a neutral mechanical alignment within 0°±3° [9-11]. These studies have found that neutral mechanical axis alignment did not improve component survival rate or that the results remain unproven, and consequently a wider margin of alignment did not compromise component longevity. There is also the concept of “constitutional varus” in which a significant number of mature healthy adults have a natural mechanical alignment greater than 3°. Restoring neutral alignment in these patients may be abnormal and undesirable, although it has no correlation with patients with knee OA or patients who have undergone TKA [25]. However, further research is required to support these hypotheses.

Studies have been performed to investigate the cause of component malalignment in computer-assisted TKA surgeries. Takasaki and coworkers used a tibial bone model to study the alignment accuracy of an image-free navigation system in severely varus deformed knees [1]. Their results suggest that image-free navigation has a tendency to cut the tibia in the varus. The preoperative tibial mechanical axis may be registered in varus compared to the postoperative tibial mechanical axis due to tibial deformities as suggested by conventional TKA studies [26-28]. The image-free navigation system may not precisely estimate the bone morphology of severely deformed knees, which may cause the tibial component to be implanted in the varus position [1]. However, their study involved deformity only in the tibia with none in femur. Furthermore, they used a different navigation system which utilized the surgeon’s registration point of the knee center instead of using the theoretical knee center determined by the computer not only by registering several anatomical landmarks but also by registering kinematics data, as in our study. The different calculated mechanical angles may account for the different outcomes of the two studies. In our current study, there was no tendency for varus malalignment, even when only comparing TCA of the S and V groups.

The present study has some limitations. First, component angles and lower limb alignment were evaluated on full-length standing radiographs in the coronal plane only and did not assess the effect of rotation on component or leg alignment. However, each radiograph was taken with the patellae pointing straight ahead with the feet internally rotated at approximately 20°, minimizing the amount of rotation on plain film. Second, final lower limb alignment was slightly worse than other navigation studies, but this may be attributed to multiple operators with various degrees of experience with the image-free navigation system although all procedures were performed or supervised by one of the two extensively trained senior authors. Improvements in registration error can be attained through further experience with the navigation system and by developing a consistent technique for registration, which may improve our results with data attained at later dates [29]. Despite these limitations, we believe that the present study shows that, with some care during surgery, the severity of preoperative varus deformity does not affect alignment of implant components and lower limb alignment when performing image-free computer navigated TKA.

In conclusion, our study shows that good component and lower limb alignment can be achieved with severe varus knees when performing TKA with an image-free computer navigated system. Consistent correction of knee alignment to within ±3° of MA achieved with image-free computer navigated TKA suggest that the severity of varus deformity does not affect component placement accuracy. Better component placement and soft tissue balancing of the knee with an image-free navigation system may decrease component wear, maximize component longevity, and improve functional outcome. However, further long term studies are needed to validate these hypotheses.

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Figure Legends

Fig 1. A 67 year old female with advanced osteoarthritis of the left knee.

A: Full-length standing radiograph revealing severe varus knee of 23˚.

B: Short-film radiograph reveals asymmetric joint space narrowing, osteophyte formation, and medial subchondral sclerosis, typical of knee OA.

C: Postoperative weight bearing full-length standing radiograph shows FCA of 89˚ and TCA of 90˚, MA=89˚+90˚-180˚=-1˚ (a slightly valgus alignment).

D: A magnified radiograph of the knee components. Careful component placement and soft tissue balancing results in MA within 3˚ of neutral limb alignment.

Fig 2. Femoral Component Angle (FCA).

Angles between dashed lines indicate ±3° from neutral limb alignment. Grey = varus group, black = severe varus group.

Fig 3. Tibial Component Angle (TCA).

Angles between dashed lines indicate ±3° from neutral limb alignment. Grey = varus group, black = severe varus group.

Fig 4. Mechanical Axis (MA).

Angles between dashed lines indicate ±3° from neutral limb alignment. Grey = varus group, black = severe varus group.

Table 1. Preoperative Demographic Data.

A summary of patient data of severe varus and varus groups.

MA = mechanical axis; SD = standard deviation

Values are shown as mean ± SD (range) or n (%) where appropriate.

Table 2. Operative Data.

A Summary of Results for Severe Varus and Varus Knees Undergoing Image-free Navigated TKA.

CR = cruciate retaining; PS = posterior stabilizing; SD = standard deviation; FCA = femoral component angle; TCA = tibial component angle; BMI = body mass index; MA = mechanical axis

Values are shown as mean ± SD (range) or n (%) where appropriate.

Figure 1A

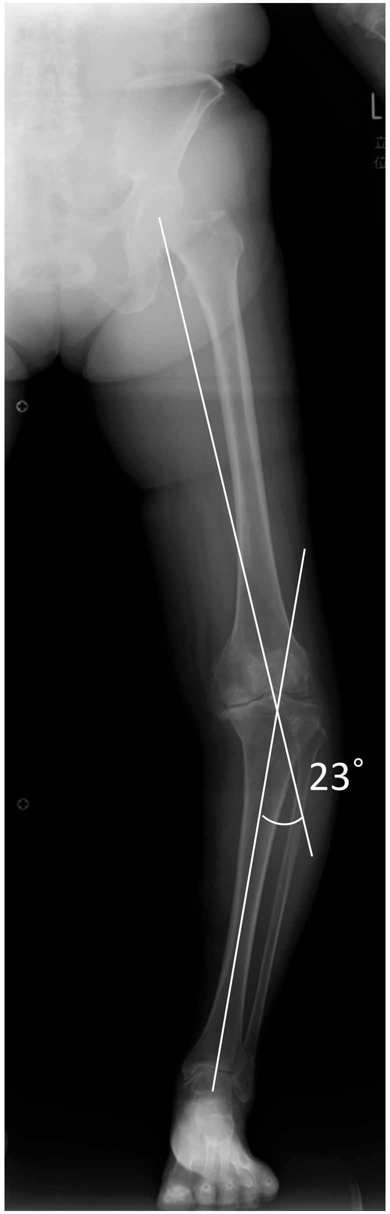


Figure 1B

Figure 1C

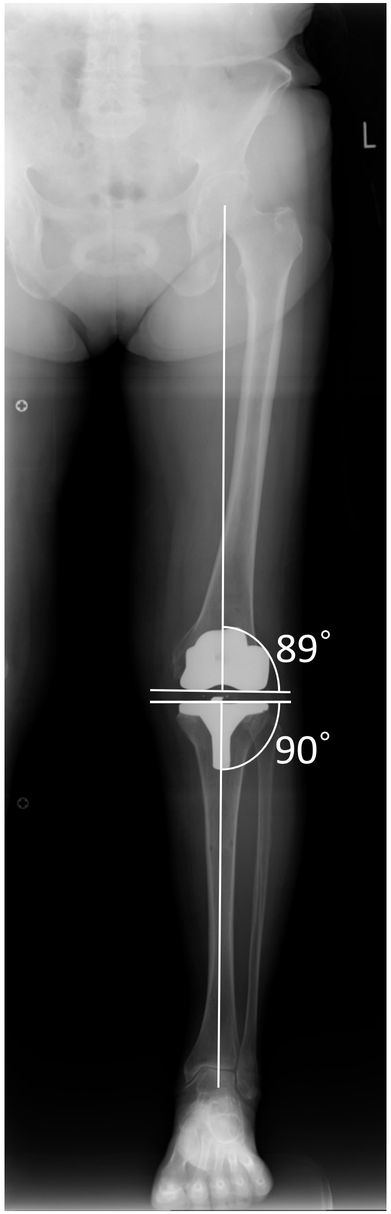
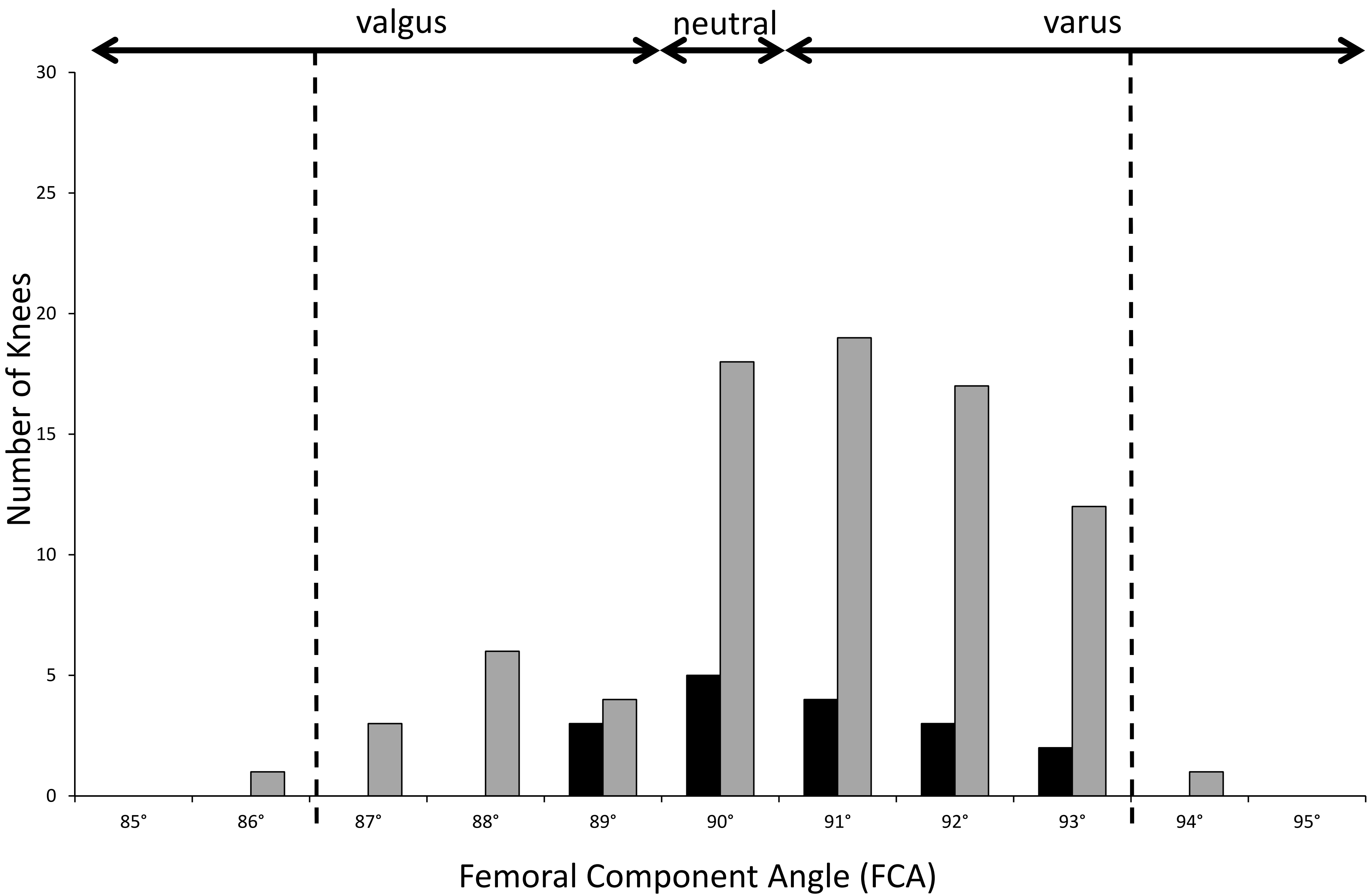


Figure 1D

Fig 2



valgus
neutral
varus
30
25
20
15
10
5
0
Number of Knees
85°
86°
87°
88°
89°
90°
91°
92°
93°
94°
95°
Femoral Component Angle (FCA)

Fig 3

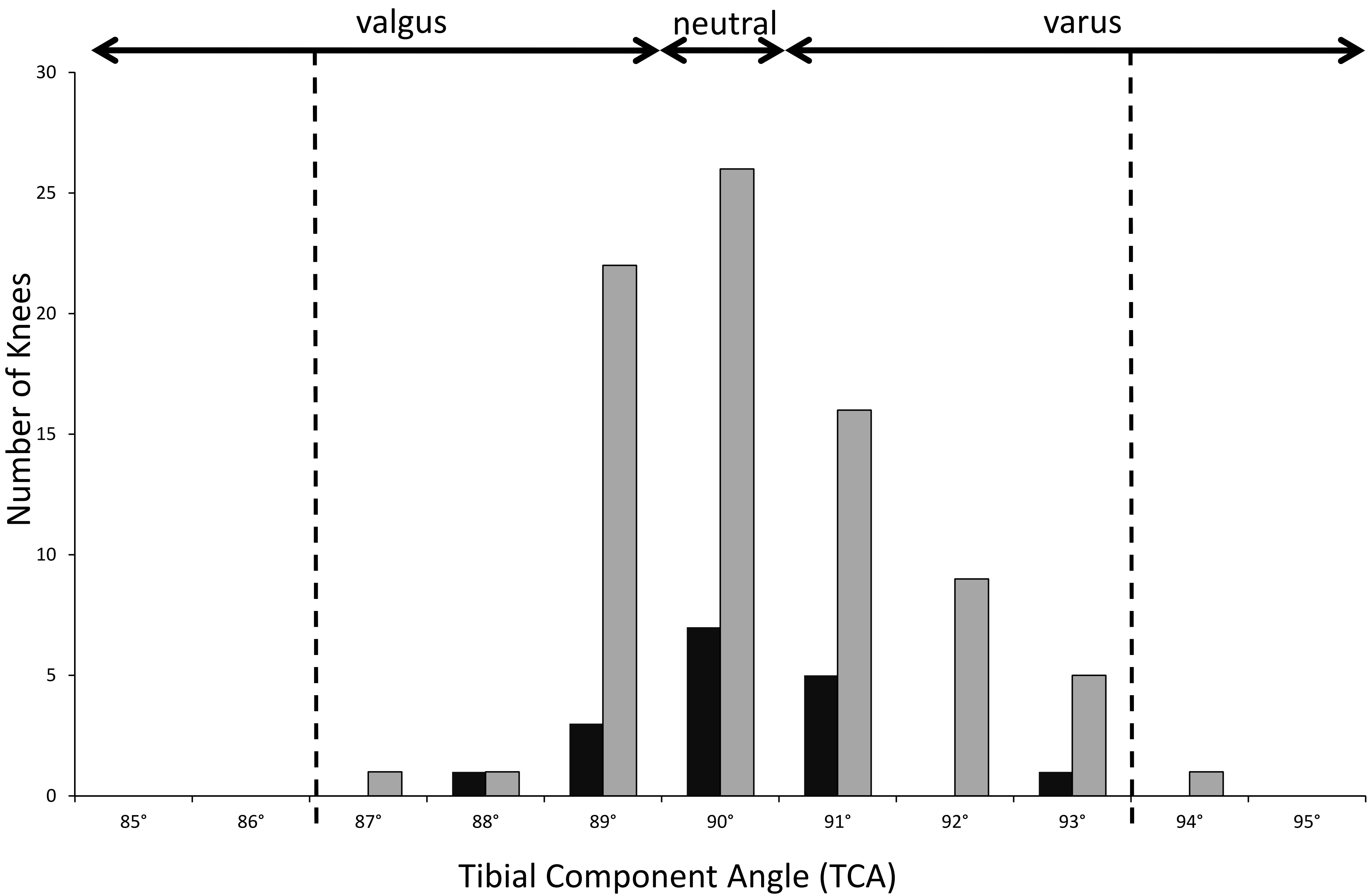
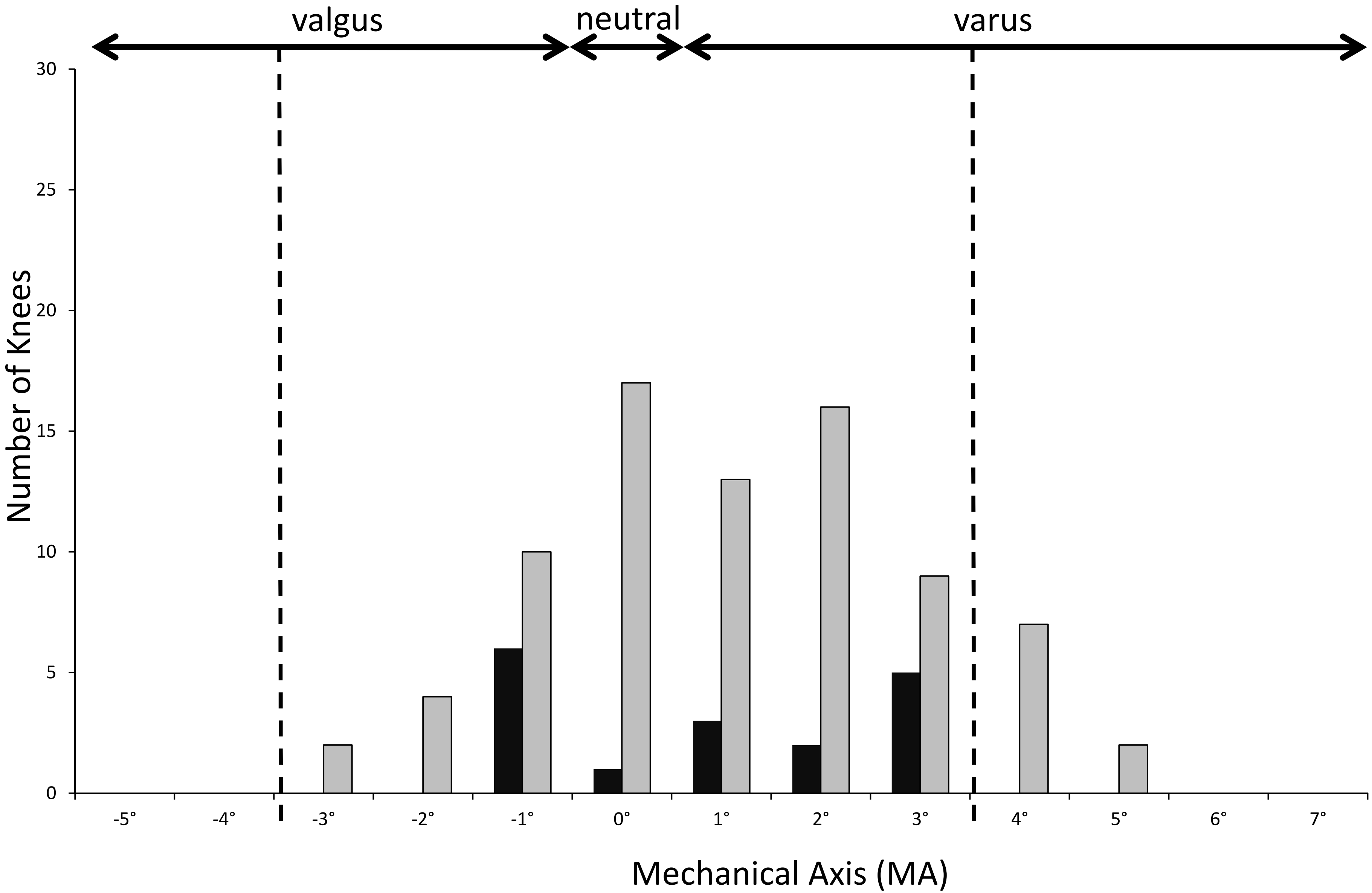

valgus
neutral
varus
30
25
20
15
10
5
0
Number of Knees
85°
86°
87°
88°
89°
90°
91°
92°
93°
94°
95°
Tibial Component Angle (TCA)

Fig 4



valgus
neutral
varus
30
25
20
15
10
5
0
Number of Knees
-5°
-4°
-3°
-2°
-1°
0°
1°
2°
3°
4°
5°
6°
7°
Mechanical Axis (MA)

Table 1

	Severe Varus Knees	Varus Knees
Number of knees	17	81
Female knees	15	72
Male knees	2	9
Mean age	75.9±4.1 yrs	73.4±5.4 yrs
Avg FCA	90.8° ±1.3°	90.8° ±2.0°
FCA >3° or <-3°	0	2
Avg TCA	90.2° ±1.1°	90.3° ±1.3°
TCA >3° or <-3°	0	1
MA within ±3°	17 knees (100%)	72 knees (88.9%)
Complications	0 (0.0%)	3 (3.7%)