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Original Article

Comparison of Postoperative Alignment of Total Knee Replacement Using Computer-Assisted Navigation with Conventional Guiding System in Chinese Population with Significant Coronal Femoral Bowing

對比傳統全膝關節置換術和電腦導航全膝關節置換術於多有股骨曲彎的中國人術後下肢角度方向的分別

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A B S T R A C T

Background/Purpose: Coronal femoral bowing is common in Chinese population. This might affect the restoration of mechanical alignment in conventional total knee replacement (TKR). The aim of the study was to compare the postoperative alignment of conventional TKR with computer-assisted navigation TKR (CAN-TKR), to investigate the effect of femoral bowing on postoperative alignment in conventional TKR and to understand the role of CAN-TKR in limbs with significant femoral bowing.

Methods: This is a retrospective study of 331 knees that underwent TKR (either conventional or CAN-TKR) in our centre from January 2010 to June 2012. The incidence of coronal femoral bowing was measured. The postoperative alignments were compared between the two groups.

Results: The incidence of excessive coronal femoral bowing was 41.4%. For patients with or without significant coronal femoral bowing, the CAN-TKR group was significantly better in restoring post-operative mechanical axis and the coronal femoral angle ($p < 0.05$). Proportions of outliers were also much less in the CAN-TKR group.

Conclusion: CAN-TKR reduces outliers in all patients, and is especially superior in restoring mechanical alignments in patients with significant coronal femoral bowing.

中 文 摘 要

背景：股骨曲彎在中國人中十分常見。這可能會影響全膝關節置換術後的效果。此研究目的是要在 此類患者中對比傳統全膝關節置換術和電腦導航全膝關節置換術對於術後下肢角度方向的分別。

方法：在2010 年一月至2012 年六月期間， 331 個全膝關節置換手術（用傳統或電腦導航方式）於本部門進行。我們計算有股骨曲彎的病人比率與及在兩種全膝關節置換手術方式中對比量度術後 下肢角度的分別。

結果：41.4%的中國人有股骨曲彎。對比用傳統方法，電腦導航全膝關節置換術後的病人有更佳的 術後下肢角度方向。

結論：電腦導航全膝關節置換術比較傳統方法，於多有股骨曲彎的中國人中有更佳的術後下肢角度 效果。

Introduction

It has been well documented that the outcome of a total knee replacement (TKR) depends significantly on the proper placement of the various components that determine the tibiofemoral alignment in the lower limb.[1–3] Malposition may cause pain, stiffness, joint instability, early polyethylene wear, and aseptic loosening.[4]

Computer-assisted navigation TKR (CAN-TKR) is common nowadays and there have been numerous studies on its accuracy in restoring optimal knee alignments[5–9] and reducing outliers.[10]

Conventionally, the intramedullary guide is used for the femoral component and the extramedullary or intramedullary guide is used for the tibial component. The accuracy of the conventional intramedullary femur guiding method may decrease in patients with

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excessive deformity of the femur (e.g., from excessive femoral bowing, distortion of bony canal, malunited fractures, and metabolic bone disease).[11–13]

According to Yau et al,[14] coronal femoral bowing is common (62%) in the Asian population. This might affect the correct positioning of the femoral component in conventional TKR, which uses the intramedullary guide for the placement of the femoral implant.

There are several objectives of this study. First, to compare the postoperative alignment of conventional TKR with CAN-TKR. Second, to determine the incidence of coronal femoral bowing in our patient population. Third, to investigate the effect of coronal femoral bowing on the postoperative alignment in conventional TKR and to determine whether CAN-TKR could produce a more accurate alignment in patients with coronal femoral bowing.

Materials and methods

Between January 2010 and June 2012, 331 knees underwent primary TKR at our hospital. The medical records and radiological data for all patients were reviewed retrospectively. Clinical data collected include age, tourniquet time, model of prosthesis, and radiological assessment (both prior to and after the operation). Patients who had revision TKR, severe extra-articular deformity of the femur or tibia related to trauma or previous surgery, and incomplete medical records were excluded. Patients were also excluded if the radiograph showed significant rotation or imperfect centring at the knee joint.

All patients in the study were evaluated with long-leg weight-bearing scanograms prior to and after the operation. The rotation of the femur in the scanogram was standardized by asking the patient to stand on a platform with both lower limbs slightly internally rotated so that the patella is directly facing forward. The X-ray tube was centred at the patella level.

The incidence of coronal femoral bowing was measured. The postoperative alignments, including the following were compared between the two groups (conventional and CAN-TKR): (1) postoperative mechanical axis (Figure 1A); (2) coronal femoral angle (90°) (θ/θ′; Figure 1B); (3) coronal tibial angle (90°) (β/β′; Figure 1B); and (4) coronal femoral bowing angle (Figure 1C).

The amount of coronal femoral bowing was measured using the method described by Yau et al.[14] The femur diaphysis was divided into four equal parts—a line was drawn in the centre of each quarter. The degree of bowing was defined as the angulation between the proximal and distal quarters of the femoral diaphysis. We defined significant femoral bowing as > 5° of angulation.

The study was divided into two parts. The whole patient population (331 knees) was first divided into two groups: those who received conventional TKR (Group A) were compared with those who received CAN-TKR (Group B; Figure 2).

Among all the patients, the ones with significant femoral bowing (i.e., coronal femoral bowing angle > 5°) were selected and further subdivided into two groups: those with femoral bowing and received conventional TKR (Group H) and those with femoral bowing and received CAN-TKR (Group K; Figure 3).

The coronal femoral angle is the angle between the mechanical axis of the femur and the tangent of the femoral component. The coronal tibial angle is the angle between the mechanical axis of the tibia and the line parallel to the tibial tray (Figure 1B).

The position of the femoral or tibial component was considered ideal if the coronal femoral angle or coronal tibial angle was 90°.

An anterior longitudinal incision with a medial parapatellar approach was used in all cases. The CAN-TKR was implanted using Stryker OrthoMap ASM Knee Navigation V1.1-7 by cutting both proximal tibial and distal femoral bones with the aim of achieving 0° valgus or varus. The conventional TKR was implanted using intramedullary femoral jig and extramedullary tibial jig. All patients received a posterior-stabilized knee system and all patellae were resurfaced. The prostheses used were the Triathlon knee system (Stryker, Mahwah, NJ, USA), GENESIS II Total Knee System (Smith and Nephew, Memphis, TN, USA), P.F.C. SIGMA Knee System (DePuy, Warsaw, IN, USA), and NexGen Legacy posterior-stabilized knee system (Zimmer, Warsaw, IN, USA). These models have different intramedullary guide-rod lengths. Each operation was carried out or supervised by a senior surgeon from the joint reconstruction team.

Measurements in both groups were analysed using independent sample t tests. The effect of excessive coronal femoral bowing on postoperative alignments in the two systems was also analysed.

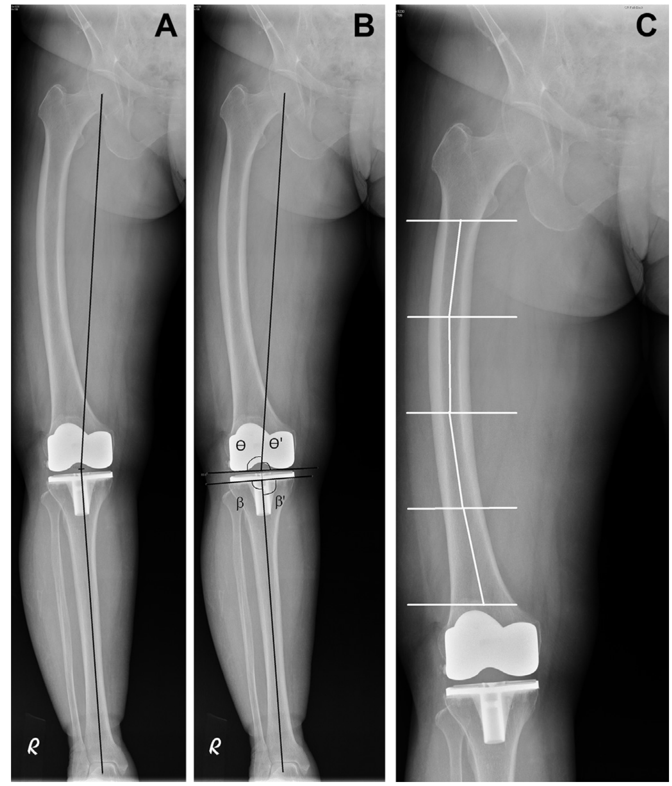

Figure 1. (A) Mechanical axis measurement. The angle between a line drawn from the centre of the hip to the centre of the distal femur and a line drawn from the centre of the tibia to the centre of the ankle. (B) Coronal femoral angle (θ or θ′, whichever is smaller). Optimal angle is 90°. Coronal tibial angle (β or β′, whichever is smaller). Optimal angle is 90°. (C) Coronal femoral bowing angle.[14] Diaphysis of the femur divided into four equal parts. A line is drawn in each quarter at the midpoint of the endosteal canal. Excessive coronal femoral bowing is defined if the angle between the most proximal and distal lines is > 5° of angulation.

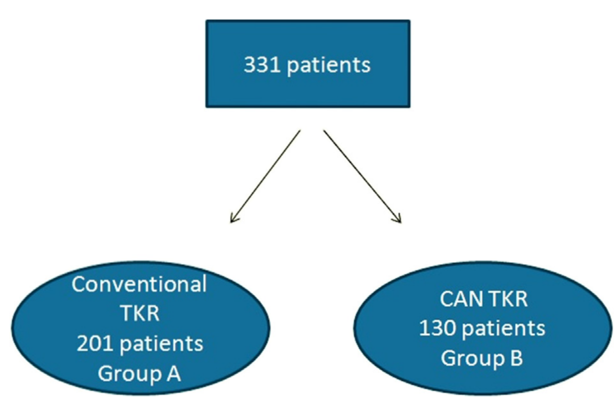

Figure 2. Classification of total patient population (n = 331): Group A (n = 201) and Group B (n = 130).

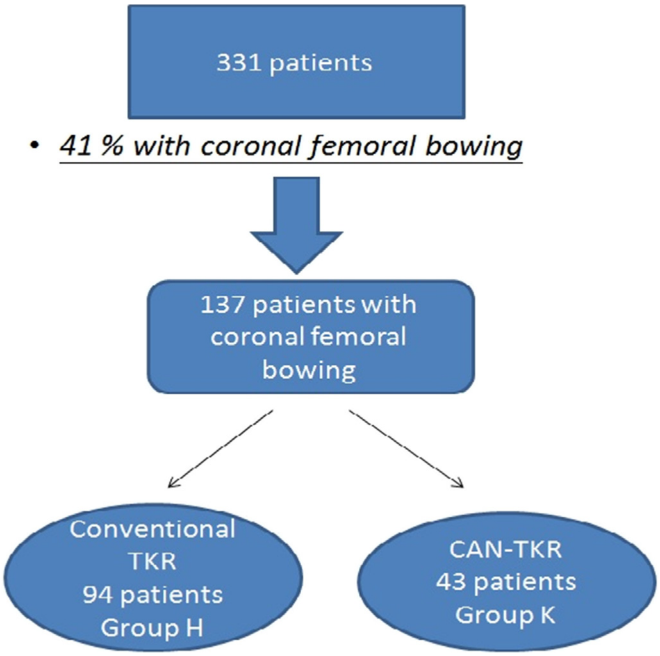

Figure 3. Subclassification of the patients with significant femoral bowing ($n = 137$): Group H ($n = 94$) and Group K ($n = 43$).

Proportions of outliers (postoperative mechanical axis > 3° varus/valgus) in the two groups were compared using Pearson Chi-square test. A p value < 0.05 was considered statistically significant.

Results

After exclusion, 331 knees (312 patients; 368 knees were evaluated) were suitable for further analysis. There were 109 men and 203 women in this study. All patients were ethnically Chinese.

There were significant differences in the postoperative mechanical axis, coronal femoral and tibial angles between the conventional group (Group A) and the CAN-TKR group (Group B; $p < 0.05$; Table 1). The difference in mechanical axis between the two groups was 1.05°. However, the difference in the coronal femoral and tibial angles was only 0.62 and 0.32, respectively. This small difference, although statistically significant, may be affected by measurement error.

In our study, the incidence of excessive coronal femoral bowing was 41.4% (with the coronal femoral bowing angle set as 5°).

For those patients with significant coronal femoral bowing, the CAN-TKR group (Group H) was significantly better in restoring postoperative mechanical axis and the coronal femoral angle ($p < 0.05$; Table 2). The difference in mechanical axis between the two groups was 1.73°, whereas the difference in the coronal femoral angle was 1.11°. The difference in the postoperative coronal tibial angle was insignificant between the two groups.

In patients with coronal femoral bowing, proportions of outliers (postoperative mechanical axis > 3° varus/valgus) were also much fewer compared with that in the CAN-TKR group.

Discussion

CAN-TKR reduces outliers in all patients, and is superior in restoring mechanical alignments in patients with significant coronal femoral bowing. Our result is the first local data in Hong Kong, and is supported by Huang et al's[15] study in Taiwan. There are other recent studies demonstrating the superiority of CAN-TKR in restoring alignments in the femur with extra-articular deformity.[16,17]

In a patient with coronal femoral bowing, it is difficult to achieve correct positioning of the femoral component and satisfactory postoperative mechanical axis in conventional TKR, which uses intramedullary guide for placement of the femoral implant.[18,19] Theoretically, this may be overcome by careful use (and with experience) of a long, fixed, and large-diameter intramedullary guide rod with preoperative templating to determine an optimal entry point location,[20–22] so that the intramedullary rod can align with the central femoral anatomic axis. However, not all TKR models have such a long and thick intramedullary guide rod, and not all models have the suitable distal femur cutting block with the appropriate distal valgus cut angle to make the distal femoral cut perpendicular to the mechanical axis in patients with femoral coronal bowing. An attempt to accurately locate an entry point even with preoperative templating may also be technically difficult. Another common mistake of using intramedullary guide in femoral bowing includes the incomplete insertion of guide rod into the femoral canal causing impingement onto the lateral femoral cortex prematurely causing varus alignment.

CAN-TKR could easily produce more accurate femoral component alignment in patients with coronal femoral bowing without the problems mentioned earlier.

In our study, the positioning of the tibial component was not improved with CAN-TKR in patients with coronal femoral bowing.

Our study supports Yau et al's[14] study in 2007 that coronal femoral bowing is common in the Chinese population. The sample size in this study was three times larger. The difference in incidence (41.4% in this study vs. 62% in Yau et al's[14] study) may be because we

Table 1
Patient characteristics and postoperative measurements

Parameters	Conventional Group A	Navigation Group B	p
No. of patients	201	130	
Age (y)	71.12	67.96	<0.001
Tourniquet time (min)	81.96	86.70	0.025
Preoperative mechanical axis	166.71°	168.28°	0.071 (insignificant)
Postoperative			
Mechanical axis	176.76° (SD, 2.18)	177.81° (SD, 1.81)	<0.001
Coronal femoral angle	87.97° (SD, 1.66)	88.59° (SD, 1.16)	<0.001
Coronal tibial angle	88.55° (SD, 1.10)	88.87° (SD, 1.02)	0.008
Number of outliers (mechanical axis > 3° varus/valgus)	83 (41.29%)	28 (21.54%)	<0.001

$n = 331$ patients.
SD = standard deviation.

Table 2
Postoperative measurements in patients with coronal femoral bowing (coronal femoral bowing angle > 5°)

Parameters	Conventional Group H	Navigation Group K	p
No. of patients	94	43	
Femoral bowing angle	8.59° (SD, 3.88)	9.07° (SD, 4.46)	0.52 (insignificant)
Postoperative			
Mechanical axis	176.03° (SD, 2.42)	177.76° (SD, 1.85)	<0.001
Coronal femoral angle	87.54° (SD, 1.85)	88.65° (SD, 1.18)	<0.001
Coronal tibial angle	88.60° (SD, 1.13)	88.83° (SD, 1.00)	0.251 (insignificant)
Number of outliers (mechanical axis > 3° varus/valgus)	52 (55.3%)	11 (25.6%)	0.001

$n = 137$ patients.
SD = standard deviation.

defined significant femoral bowing as more than 5° of angulation, whereas Yau et al[14] used 2° of angulation. As a result of this study, we recommend patients with coronal femoral bowing, which is common in Chinese population,[14,23] to use CAN-TKR instead of conventional TKR. A preoperative long-leg weight-bearing scanogram is required to determine coronal femoral bowing because coronal femoral bowing is not clinically apparent.

Our study has limitations. First, this was a retrospective study, so there may be subtle bias while deciding between conventional and CAN-TKR. Second, we did not address any correlation between postoperative alignment and functional outcome. Long-term results for both techniques are needed to determine whether CAN-TKR results in improved long-term outcome. Third, there was unavoidable X-ray measurement error contributed by both measurer and patient's lower limb positioning. Fourth, the radiographic assessment was done by only one surgeon.

Conflicts of interest

All contributing authors declare no conflicts of interest.

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