Coronal bowing of the femur and tibia in Chinese: its incidence and effects on total knee arthroplasty planning

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ABSTRACT

Purposes. To study the incidence of femoral or tibial bowing in the coronal plane in a Chinese population, and how it affects the accuracy of bone cuts for total knee replacement when an intramedullary alignment system is used.

Methods. Standing radiographs of the entire lower limb of each patient with end-stage primary osteoarthritis of the knee were analysed. All radiographs were digitised and the extent of bowing in the coronal plane measured. A bowing was marked if an angulation was more than 2 degrees. The projected error of cutting was then calculated.

Results. Of 93 lower limbs, 58 (62%) of the femurs had marked bowing in the coronal plane; 41 (44%) had a mean lateral bowing of 5.3 (standard deviation [SD], 3.2) degrees; 17 (18%) had a mean medial bowing of 4.4 (SD, 1.9) degrees. Marked tibial bowing in the coronal plane was less common (30 tibias, 32%). If a cutting error of more than 2 degrees was considered unacceptable, significantly more unacceptable cuts would ensue in the groups with marked bowing (p=0.003 for femurs and p<0.001 for tibia, respectively).

Conclusion. The incidence of femoral or tibial bowing in the coronal plane was high in a Chinese population with end-stage osteoarthritis of the knee. This phenomenon may increase bone cut errors in total knee replacement if an intramedullary alignment system is used and the extent of bowing is not recognised.

Key words: arthroplasty, replacement, knee; femur; tibia

INTRODUCTION

The survivorship of total knee replacement (TKR) depends on the correct restoration of the mechanical axis of the leg and the accuracy of bone cuts. The cuts of the femur and tibia should be made perpendicular to their respective mechanical axes in the coronal plane. Bone cut errors should be within 3 degrees from the ideal position.1–3

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Nonetheless, the success of the intramedullary alignment systems could be jeopardised in the presence of marked bowing. Potential cutting errors might result if the usual short radiograph of the knee is used and a constant relationship of either valgus 5º, 6º, or 7º between the distal femoral anatomical axis and the mechanical axis of the femur assumed.

We investigated the incidence and severity of femoral and tibial bowing in a Chinese population using standing radiographs of the entire lower limb in patients with primary osteoarthritis of the knee and discussed the implications of bowing on the accuracy of bone cuts when using an intramedullary alignment system.

**MATERIALS AND METHODS**

101 TKRs were performed in our hospital from July 2000 to June 2001 inclusive. 87 of them were for primary osteoarthritis (58 bilateral and 29 unilateral). Standing anteroposterior radiographs of the entire lower limb were taken, with the feet in 20º of internal rotation. 13 radiographs of the contralateral side in patients having unilateral TKR were added to make a total of 100 radiographs. The inclusion criteria were: patients of Chinese races and with a diagnosis of primary osteoarthritis of the knee. Seven radiographs were later excluded because of improper rotation (n=4) and previous surgery (n=3). Thus, a total of 93 radiographs were reviewed.

The radiographs were digitised using a VXR-12 plus film digitiser (VIDAR, Denmark) and measurements made using Imagika software (Clinical Management Corporation, New Jersey, USA). The mechanical axis of the femur was defined as the line joining the centre of the femoral head and the intercondylar notch, whereas the mechanical axis of the tibia was defined as the line joining the midpoint of the 2 tibial eminences and the midpoint of the dome of the talus (Fig. 1). The coronal bowing of the femur was measured by dividing the femoral diaphysis into 4 equal parts. A line that best described the midpoints of the endosteal canal of the femoral diaphysis is drawn in each quarter (C, D, E, and F). A line that best describes the midpoints of the endosteal canal of the tibial diaphysis is drawn in each third (G, H, and I).

Superior results to extramedullary systems. Nonetheless, the success of the intramedullary alignment systems could be jeopardised in the presence of marked bowing of the bones. The osteometry of Asian skeletons differs considerably from that of western populations. Bowing of the femur and tibia is not uncommon among Asians with end-stage osteoarthritis of the knee. This may potentially affect bone cuts in TKR, especially if an intramedullary alignment system is used. A standing radiograph of the entire lower limb should be used for preoperative planning to identify any marked bowing. Potential cutting errors might result if the usual short radiograph of the knee is used and a constant relationship of either valgus 5º, 6º, or 7º between the distal femoral anatomical axis and the mechanical axis of the femur assumed.
thirds of the tibial diaphysis. A bowing was marked if the overall angulation was $>2^\circ$. The direction of bowing was defined as lateral if the distal axis angulated towards the midline with reference to the proximal axis; and medial if the distal axis angulated away from the midline (Fig. 2).

The expected pathways of the intramedullary alignment rod were drawn on the femur (a line joining the intercondylar notch of the distal femur to the midpoint of the endosteal canal at the femoral isthmus) and tibia (a line joining the midpoint of the 2 tibial eminences to the midpoint of the endosteal canal of the tibial isthmus) [Fig. 3]. The valgus correction angle of the distal femur was defined as the angle between the femoral mechanical axis and the line joining the intercondylar notch and the femoral isthmus (Fig. 3). This angle determined the choice of the distal femoral cutting block to achieve a perpendicular distal femoral bone cut to the mechanical axis of the femur.

The potential cutting error of the distal femur was estimated by calculating the difference between the valgus correction angle and the standard distal femur cutting block of valgus 5°, 6° and 7°, respectively. The potential cutting error of the tibia was estimated by calculating the angulation between the mechanical axis of the tibia and the line joining the midpoint of the tibial eminences and the midpoint of the tibial isthmus. The potential cutting error was considered significant if there was a deviation of $>2^\circ$ from the ideal cutting plane (either varus or valgus). The potential cutting errors in the femur and tibia were compared between the group with and without marked bowing. Statistically significant association was assumed if $p<0.05$.

RESULTS

93 standing radiographs of the entire lower limb were taken from 10 men and 43 women aged 45 to 81 (mean, 67; standard deviation [SD], 8) years. The mean coronal bowing of the femurs was 1.6° laterally (SD, 4.4°; range, 9.1° medially to 19.7° laterally). 58 (62%) femurs were markedly bowed, with $>2^\circ$ angulation: 41 (44%) had lateral bowing (mean, 5.3°; SD, 3.2°) and 17 (18%) had medial bowing (mean, 4.4°; SD, 1.9°) [Table 1].
The mean coronal bowing of the tibias was 0.6° laterally (SD, 2.6°; range, 8.4° medially to 8.5° laterally). Only 30 (32%) of the tibias were markedly bowed: 20 (22%) were laterally bowed (mean, 4.2°; SD, 1.5°); 10 (11%) were medially bowed (mean, 3.5°; SD, 1.9°).

The mean potential cutting error on tibias using the intramedullary alignment system was 0.5° (SD, 1.5°; range, valgus 5.9° to varus 4°) [Table 3]. If >2° error was made in the expected tibial cut, 12 (40%) cuts in the bowed tibia group and only 4 (6%) in the straight tibia group would have had an unacceptable error (p<0.001, Chi squared test).

**DISCUSSION**

The osteometry of Asians differs from that of western populations in both size and morphology. It is clinically significant as nearly all commercial TKR systems are based on a model of western osteometry. The joint line of the knees in a group of young healthy Chinese was more varus than Caucasians. The mean angle of the transepicondylar axis and posterior condylar line in cadaveric distal femurs of Chinese races was 5° external rotation, compared with 3° in Caucasians. The angle between the anterior shaft of the tibia and the slope of the tibial plateau in the sagittal plane was 14.7° in Chinese and 10° in Caucasians. This affects the intended posterior cutting slope of the tibial plateau when an extramedullary alignment system is used. Excessive distal femoral bowing in a lateral plane had an impact on the use of a stemmed femoral prosthesis. The femoral medullary canal was often not straight in Japanese patients, and the central line of the proximal femoral diaphysis formed an angle of 2° with the central line of the distal diaphysis. In the present study, the incidence of bowing was high: up to 62% of patients had a femoral bowing of >2°; most (44%) were laterally bowed, the most severe
being 20°. Tibial bowing was less frequent (32%) and less severe (mean, 0.6°; SD, 2.5°). Anterior bowing of the femur in a sagittal plane can lead to apparent femoral bowing on anteroposterior radiographs if the limb is not in correct rotation. However, the error caused by rotation of radiographs is only 2.5° even if the limb was rotated 40°.

Standing radiographs of the entire lower limbs are useful in measuring bowing and choosing correct valgus correction angles. In populations with a high incidence of femoral bowing, surgeons should be cautioned against routinely using short films for TKR planning coupled with a distal femoral cutting block with a constant valgus correction angle.

In a group of Chinese patients, a potential cutting error of >2° in 22% of tibias was observed if an intramedullary alignment guide was used for tibial cuts. The findings of our study echoed theirs. Thus, we recommend using an extramedullary alignment system for the preparation of tibial cuts in patients with marked tibial bowing.

The potential errors of the femoral and tibial cuts represent planning errors only. Errors may also arise from actual bone cutting and prosthesis implantation. The final errors are very likely underestimated. In expert hands, the actual error in bone cutting was around 1°. As the acceptable error in prosthesis alignment is <3°, a potential planning error of >2° is considered unacceptable.

**CONCLUSION**

Coronal bowing of the femur or tibia in Chinese patients with end-stage primary osteoarthritis of the knee is common (femur, 62%; tibia, 32%) and sometimes severe (maximal lateral femoral bowing being 20°). We recommend using anteroposterior radiographs of the entire lower limb to measure the extent of bowing for preoperative planning. If marked bowing is encountered, an extramedullary alignment system or computer navigation (instead of an intramedullary alignment system) should be used to enhance the accuracy of bone cutting.

**REFERENCES**