Original Article

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Do We Get a "Real" Alignment of Knee in the Preoperative Planning of High Tibia Osteotomy: A Prospective Study of Reproducibility

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Background. Precise preoperative measurement of knee alignment is needed to calculate the accurate angle of correction at proximal tibia osteotomy for medial gonarthrosis.

Methods. We performed a prospective study to compare the reproducibility of measuring the mechanical and anatomical axes. Thirty-two patients (32 knees) with medial compartment osteoarthritis to be treated with proximal tibia osteotomy were included in this study. Preoperatively, whole lower limb roentgenographs were obtained twice, and 2 independent radiologists measured the mechanical and anatomical axes from each roentgenograph.

Results. Measurement of mechanical and anatomical axes had a mean variability of 2.22 and 1.88 degrees, respectively, which was not statistically significant (p = 0.267) in the assessment of reproducibility. With the anatomic axis, however, we found 0.61 degree of variability to the roentgenographic procedures and 1.30 degree to the radiologists (p = 0.007). With the mechanical axis, the corresponding findings were 1.30 degree and 1.02 degree (p = 0.167). Despite the relative small number of patients in this series, errors in measurement of the anatomical axis seem mostly to originate from different radiologists, whereas errors in measurement of the mechanical axis seem to originate from both the radiologists and the procedures. The maximum variability in measuring both axes was 3 degrees, which is highly significant for a reliable calculation of the wedge when performing proximal tibia osteotomy.

Conclusions. We suggest that, for accuracy and economy, measurement of the anatomical axis might be better. Furthermore, by measuring either mechanical or anatomical axis, the errors originating from roentgenographic measurement of knee alignment should be considered in preoperative planning.

It is widely accepted that, with certain indications, high tibia osteotomy is a reliable surgical procedure for knees with unicompartment osteoarthritis and an angular deformity.[1-3] Most authors agree that postoperative alignment with slightly valgus over-correction can contribute to a better long-term result.[4-6] In order to obtain ideal postoperative alignment, a reliable method of measuring the knee deformity is necessary for preoperative evaluation. There are 2 common ways to measure knee alignment: the mechanical axis (hip-knee-ankle axis angle) and the anatomical axis (femoral-tibia axis angle). While a majority of authors measured the anatomical axis to evaluate knee alignment in performing a high tibia osteotomy,[4,6] others preferred to measuring the mechanical axis.[5,7] However, there is still no consensus concerning which is more reliable in measuring the alignment of the knee to be treated with high tibia osteotomy.

The purpose of the present study was to evaluate the reproducibility of measurements of the mechanical and anatomical axes and to assess the reliability of the knee alignment we got in preoperative planning of high tibia osteotomy.

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METHODS

Thirty-two patients (32 knees) with medial gonarthrosis who were to be treated with high tibia osteotomy were enrolled in this prospective study. Two radiographs were taken of each knee under the supervision of 2 independent radiology assistants. Two independent national-boarded experienced radiologists measured the anatomical axis and mechanical axis using each roentgenogram. Therefore, 4 independent measurements of the anatomical axis and 4 independent measurements of the mechanical axis were obtained for each knee.

Preoperatively, a whole lower limb (including hip, knee and ankle) standing antero-posterior (AP) triple film was performed on each knee using three 14 × 17 × 3-inch X-ray graduated grid cassettes. The X-ray tube was placed 10 feet from the patient and centered on the knee. The patient was asked to stand on the involved leg with the foot pointed foreword. The patient then left the examination room and returned to the room 30 minutes later. The second radiograph was performed under the supervision of another radiology assistant using the same procedures as the previous radiograph.

The mechanical axis of the femur is defined as a line from the center of the femoral head to the center of the intercondylar notch and then extending distally. The mechanical axis of the tibia runs from the center of the tibia plateau to the center of the tibia plafond. The medial angle formed between these 2 separate mechanical axes of the femur and tibia determines the mechanical axis of a knee with genu varum deformity. The anatomical axis is represented by the medial angle that is formed by the intersection of the lines drawn through the long axes of the femur and tibia.[8]

We determined the variability of the measured values to assess their reproducibility. Four independent measurements of each axis (anatomical and mechanical) were obtained from a single knee. The variability of measured values of the axes was obtained by the maximum of the 4 values minus the minimum. We compared the mean variability between the measurements of the anatomical and mechanical axes of 32 knees to determine which method was more reproducible.

To further understand whether the errors of measurements were generated mainly from the roentgenographic procedure or from differences among radiologists, we compared the mean variability from different films measured by the same doctor [Appendix 1] and the mean variability from different doctors measuring the same film [Appendix 2]. We used the paired *t*-test for statistical analysis. The data were expressed as mean ± SD.

RESULTS

The mean variability of measurements of the anatomical axis from 32 knees was 1.88 ± 0.99 (0-3) degrees, while that of the mechanical axis was 2.22 ± 0.71 (1-3) degrees. There was no statistically significant difference between the measurements (p = 0.267). The mean variability from different films of the anatomical axis measured by the same doctor (i.e., the error from the roentgenographic procedure) was 0.61 ± 0.48 (0-1.5) degree; the mean variability from different doctors measuring the same film (i.e., the error from the doctors) was 1.30 ± 0.80 (0-2.75) degrees. The difference was statistically significant (p = 0.007). These results indicate that the errors in measuring the anatomical axis seem to arise mainly from the radiologists.

For the mechanical axis, the mean variability from the roentgenographic procedure was 1.30 ± 0.59 (0.5-2.25) degrees, and the mean variability from the radiologists was 1.02 ± 0.54 (0.25-1.75) degrees. The difference was not statistically significant. (p = 0.167). These results indicate that the errors from the roentgenographic procedure and the different radiologists seem to be of the same importance when measuring the mechanical axis. The maximum measuring variability of both axes was 3 degrees.

DISCUSSION

Many factors contributed to errors when measuring the mechanical and anatomical axes. The errors in measuring the mechanical axis seem to arise mainly from measurement of the femur. For example, the task of setting the center of the femoral head is very subjective. As the X-rays did not enter the notch in parallel, it became problematic to set the center of the femoral intercondyle notch because of the double images of the notch inlet and

outlet. These errors were also altered with the change in angle of the X-ray entering the patient. With the anatomical axis, femoral bowing and tibia deformity would be the most common causes of errors. There was usually varus deformity in the proximal tibia of patients undergoing high tibia osteotomy; therefore, doctors should set the anatomical axis of the tibia and femur in the diaphysis area to avoid errors.

Odenbring *et al*.[7] have performed a roentgenographic study to assess the reproducibility of mechanical axis in 8 patients with medial gonarthrosis and found that the assessment of mechanical axis had a variability of 2 degrees at most, which is highly significant for a reliable calculation of the wedge at high tibia osteotomy. In our view, however, their patient number is too small to make such conclusion. Besides, the reproducibility of the anatomic axis was not discussed and the generation of error was not further evaluated. In the current study, the error of measurement of the anatomical axis seems to arise mainly from the doctors rather than from the roentgenographic procedure. However, the error of measurement of the mechanical axis seems to arise from both doctors and procedures. Therefore, theoretically, 2 individual doctors might be needed in order to reduce errors of measurement of the anatomical axis, while the average values measured 2 doctors by taking 2 roentgenographs might be needed to improve the accuracy of the mechanical axis measurement. Hence, for accuracy and economic reasons, measurement of the anatomical axis seems to be preferred over measurement of the mechanical axis.

A majority of scholars agree that some over-correction should be applied on patients undergoing high tibia osteotomy.[4-6] Others have pointed out that under-correction often leads to an ineffective operation.[1,9] To obtain a desired postoperative alignment, it requires a good preoperative assessment of knee alignment, a precise guide instrument, and an intraoperative precision of technically obtaining. The precision of the osseous correction with the use of a guide instrument can be expected to be within 3 degrees in most cases.[10] This study indicated that the mean variability in measuring the anatomical axis was 1.88 degrees, while the mean variability in measuring the mechanical axis was 2.22 degrees. The maximum variability in measuring the anatomical and mechanical axes were both 3 degrees, which is highly significant for a reliable calculation of the wedge and could influence the chosen angle of correction when performing proximal tibia osteotomy. Thus, to reduce bias, it might be better to measure the knee alignment in duplicate. Furthermore, the errors originated from roentgenographic measurement of knee alignment should be considered in preoperative planning.

Osteotomy of the proximal part of the tibia for painful osteoarthritis of the medial compartment of the knee is a well-defined and generally accepted procedure that usually results in relief of pain.[11] With ideal candidate, good preoperative planning, and precise technique at surgery, promising long-term result can be expected.[10]

Appendix 1

Mean variability from different films measured by the same doctor

$$\left(\frac{|F1D1 - F2D1| + |F1D2 - F2D2|}{2} \right)$$

(i.e., the error from the roentgenographic procedure)
We named the 2 doctors as Doctor 1 (D1) and Doctor 2 (D2) and named the 2 radiographs as Film 1 (F1) and Film 2 (F2). FxDy: the axis measured from film x by doctor y.

Appendix 2

Mean variability from different doctors measuring the same film

$$\left(\frac{|F1D1 - F1D2| + |F2D1 - F2D2|}{2} \right)$$

(i.e., the error from the doctors)

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