Evaluation of the flexion gap by axial radiography of the distal femur

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The shape of the flexion gap in 20 normal knees was evaluated by axial radiography of the distal femur, and the results compared with those obtained in a previous study by MRI. The observed asymmetry was reduced by 29% using radiography, with a mean value of 3.6° (1.5° to 6.3°) compared with that obtained by MRI of 5.1° (2.6° to 9.5°), a mean discrepancy of 1.49°. The results obtained by radiography and MRI showed a strong correlation (r = 0.78).

Axial radiography is acceptable for the evaluation of the flexion gap and is less expensive and more comfortable to perform than MRI. Additionally, no metallic artefact occurs when the radiological method is used for assessment after arthroplasty.

Soft-tissue balancing of the knees is related to the outcome of total knee replacement (TKR). Preparing equal sized and rectangular extension and flexion joint gaps is an important goal in TKR because it facilitates restoration of joint kinematics.1,2 The lateral tibiofemoral articulation is physiologically lax in flexion, and thus the flexion gap in normal knees is not rectangular.3-5 The shape of the flexion gap is difficult to visualise, and there has been a paucity of quantitative data on its shape and width in both normal and degenerative knees.

We have recently reported the asymmetry of the flexion gap with a lateral opening of 5° MRI under varus/valgus stress.6 Although MRI enables three-dimensional visualisation of the knee at various flexion angles and under various forces, it is time-consuming, costly and more importantly, painful when applied to patients with knee pain. Recently, Kanekasu, Kondo and Kadoya7 reported on axial radiography of the distal femur for the evaluation of rotation of the femoral component after TKR, and suggested the possible usefulness of this technique for evaluation of the flexion gap. We have modified their technique by adding a 1.5 kg weight at the patient’s ankle for reproducible visualisation of the flexion gap.

The aim of this study was to prove the usefulness of this modified axial radiography compared with the results obtained in the previous MRI study. We hypothesised that this gravity-stressed

Fig. 1

Positioning of the patient for axial radiography of the femur. The arrow shows the path of the beam. This position is comfortable for patients with knee disorders.
Radiography would have comparable reproducibility and good correlation with results obtained from MR images.

**Patients and Methods**

Twenty volunteers, ten male and ten female with a mean age of 27.2 years (18 to 53), who had taken part in the previous study each had one knee re-examined by axial radiography at a mean of 8.4 months (2 to 14) since the MRI. They had no symptoms and their radiographs and MRIs showed no abnormalities. The study was approved by our institutional review board and all patients gave informed consent.

The details of the MR scans and measurements have been published previously. Axial radiography of the distal femur with 1.5 kg distraction force. Axial radiographs of the distal femur were obtained with a modification of the technique recently reported by Kanekasu et al. Subjects sat on a table with their lower legs dependent and a 1.5 kg weight attached at the level of the ankle (Fig. 1). They were instructed to relax the leg muscles, especially the quadriceps. This arrangement allowed clear visualisation of not only the epicondyles of the femur, but also the shape and width of the flexion gap (Fig. 2). The asymmetry of the flexion gap was expressed as the angle between the two reference lines as used in the MRI study, namely the posterior condylar axis and the tibial articular line (Fig. 2, lines C and D).

**Measurements and statistics.** Image data were transferred to a personal computer (Apple Macintosh; Apple Compu-
ter Inc, Cupertino, California) and the angle between the posterior condylar axis and the tibial articular line was measured using an image analysis program, NIH Image (National Institutes of Health, Bethesda, Maryland). Measurements were taken by two observers in duplicate and inter- and intra-observer error examined. Results were analysed using Statview 5.0 (Abacus Concepts Inc, Berkeley, California).

Results

No subject reported pain in the knee or discomfort during axial radiography, whereas the MRI examination which required cross-legged and reversed cross-legged positions for approximately 6.5 minutes each, was frequently painful.

Based on the previous studies, the asymmetry of the flexion gap was calculated to be a mean of 5.1˚ (2.6˚ to 9.5˚). In the axial radiographs, the application of the distraction force significantly increased the size of the flexion gap, especially on the lateral side (Fig. 3). In knees with varus osteoarthritis the asymmetry of the flexion gap was clearly shown (Fig. 4). When used in patients after TKR, the flexion gap was visualised without artefacts due to the metal prosthesis (Fig. 4).

The flexion gap angles obtained by axial radiography were significantly smaller than those obtained from MR scans, with a mean value of 3.6˚ (SD 1.3˚; 1.5˚ to 6.3˚) (p < 0.0001, paired t-test). Thus the radiological results showed a lesser degree of asymmetry by 29% (-9% to 56%). The mean discrepancy between the two methods was 1.49˚ (SD 1.0˚; 0.3˚ to 4.3˚). The results obtained from axial radiography and MRI showed a strong correlation (r = 0.78; p < 0.001; Fig. 5). The mean inter-observer difference in 20 knees was 0.4˚ (SD 0.3˚; 0.1˚ to 1.3˚) and the mean intra-observer difference was 0.2˚ (SD 0.2˚; 0˚ to 0.9˚), which are comparable to those found in the MRI study.
Operative imbalance of the flexion gap in the knee with varus or valgus deformities, and the extent of soft-tissue balancing can be adjusted accordingly. When used for post-operative evaluation, this radiological technique enables assessment of the soft-tissue balancing in flexion without metallic interference. Further analysis is necessary to establish the correlation between the pre- and post-operative flexion gap assessments made using axial radiography and the intra-operative measurement results using quantitative tensioning devices.

A possible limitation of axial radiography is that quadriceps contraction could affect the shape and width of the flexion gap. It was thus essential that the subjects relaxed during the examination. We tried various loads on the ankle joint and found that gap width was not directly proportional to the amount of distraction force, and that 1.5 kg weight was suitable in terms of the subjects’ comfort and the reproducibility of the results.

In conclusion, this technique of gravity-stressed plain axial radiography of the flexed knee has an accuracy comparable to that of MRI, and is useful for the clinical evaluation of the flexion gap in normal knees.

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