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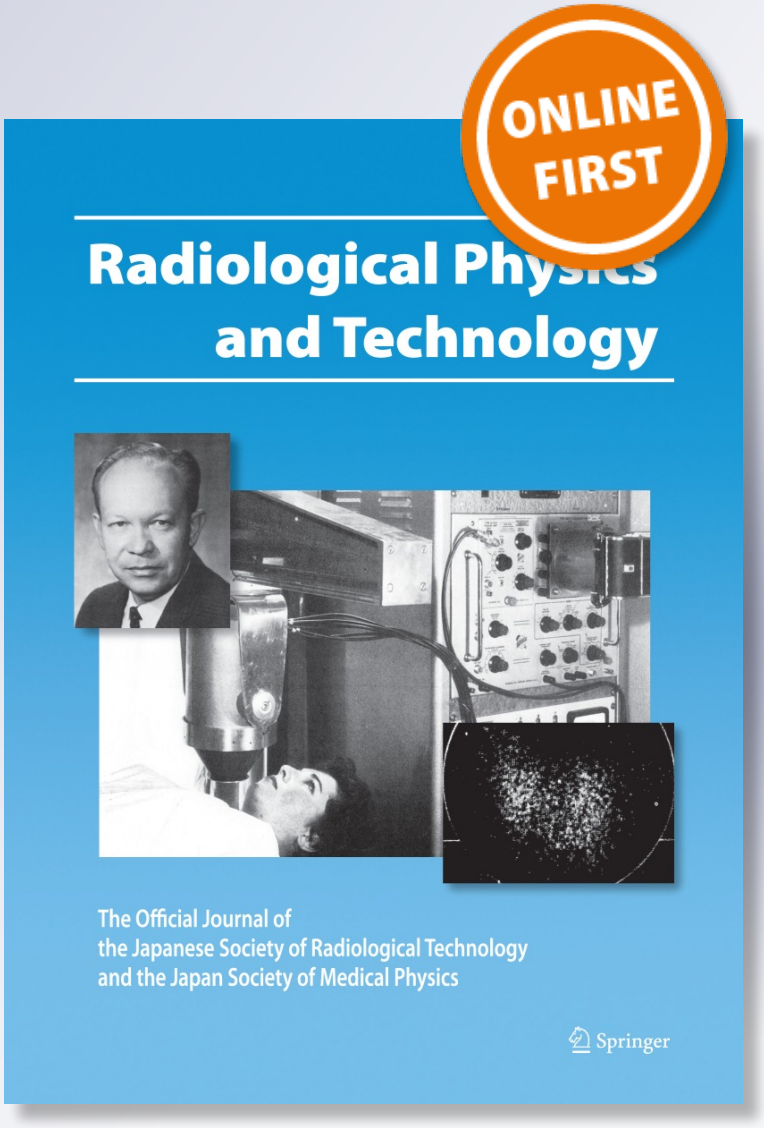

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A skyline-view imaging technique for axial projection of the patella: a clinical study

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Abstract Our purpose in this study was to evaluate the clinical usefulness of a new skyline-view imaging technique for axial projection of the patella with use of the anterior border of the patella and tibial tuberosity as position indicators. Our database consisted of pairs of axial images of the patella of the same patients, obtained with use of conventional and new techniques for the radiographic diagnosis of knee-joint diseases. A total of 118 pairs of knee images were obtained from 103 patients ranging in age from 16 to 86 years (mean age 49.7 years). The patellar axial positioning errors were determined in each of the images obtained with the two techniques. The relative error according to the patellar tilt was determined from each of the axial images of the patellas of the same patients obtained with the conventional and new techniques for the radiographic diagnosis of knee-joint diseases. The patellar axial positioning error was 0.40 with the conventional technique, whereas that with the new technique was significantly different at 0.30. This clinical study confirmed that the new skyline-view imaging technique, which uses the anterior border of the patella and the tibial tuberosity as position markers that can be confirmed by palpation, provides more accurate axial images than the conventional imaging technique.

M. Koike (✉) · H. Nose · S. Takagi · A. Akimoto · T. Kaji
Radiological Center, National Defense Medical College Hospital, 3-2, Namiki, Tokorozawa, Saitama 359-8513, Japan
e-mail: koike@ndmc.ac.jp

M. Koike
Graduate School of Health Science, Suzuka University of Medical Science, 1001-1, Kishioka-Cho Suzuka, Mie 510-0293, Japan

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1 Introduction

Axial images of the patella are important in the diagnosis of lesions such as patellar instability caused by subluxation. Axial projections are obtained along with anteroposterior and lateral views for diagnosis of conditions such as osteoarthritis of the knee, rheumatoid arthritis of the knee, and anterior patellar pain. Merchant et al. [1] proposed a skyline-view imaging technique for obtaining axial images of the patella. This imaging technique relies heavily on the experience of radiologic technologists because they assess a patient's knee flexion angle subjectively and have to decide on the X-ray incidence point and the incidence angle. Therefore, there is the limitation that this technique cannot provide a consistent quality of images. It is necessary to set the knee flexion to 30° in skyline-view imaging [2, 3]. However, the patellofemoral-joint space does not often appear in the skyline images because the knee is close to the radiography cassette.

Ahamad et al. [4] investigated the patella, patellar ligament attachment site (called the "tibial tuberosity"), and knee function. In normal patients, they reported that no changes caused by knee flexion were observed in the positional relationship between the patella and the patellar ligament, and that changes in the traction vector in patients with patellar ligament adhesion resulted in a change in the positional relationship. In our previous study, we proposed a new skyline-view technique in which radiologic technologists can select an X-ray incidence point and incident angle using markers that can be confirmed by palpation [5]. We showed that the new imaging technique is reproducible

and standardizable, with no individual variations among radiologic technologists. In the present study, we evaluated the clinical usefulness by introducing the new technique into clinical practice.

2 Methods

This study was conducted with the approval of the ethics review committee of our facility.

2.1 Subjects

The clinical study included 103 patients (118 knees) whose patellar axial images were obtained with use of both the conventional and new techniques from August 2012 to June 2013. We excluded patients who underwent total knee arthroplasty for conditions such as osteoarthritis because it is difficult to obtain X-ray images of artificial joints. The mean age of the patients was 49.7 years, and they included 48 males (52 knees; mean age 45.5 years) and 55 females (66 knees; mean age 53.0 years). We maintained a knee flexion angle of 60° for the new technique. In addition, the incident angle was set at 19° to the reference line between the anterior border of the patella and the tibial tuberosity. Because this reference line has a lateral tilt of 15° (quadriceps angle), the incident X-ray angle was adjusted so that it was parallel to the longitudinal axis of the tibia passing through the tibial tuberosity. Then, X-rays were directed toward the femoral head (at an angle 6° medial to the longitudinal axis of the femur). The patella, patellofemoral-joint space, and femoral condyle were captured in the projected images, with the tibial tuberosity and the lateral condyle of the femur overlapping partially.

The computed-radiography cassette was placed on the thigh perpendicular to the tube angle. The imaging conditions were as follows: tube voltage of 50 kV; tube current of 200 mA; imaging time of 0.1 s; X-ray tube incidence point distance of 110 cm; distance between incidence point and film of 20 cm. (Fig. 1).

We used an X-ray imaging device, an X-ray high-voltage device, and an image reader, which were BENEO (Fujifilm Medical, Tokyo, Japan), UD150L-40 (Shimadzu, Kyoto, Japan), and FCR-XL2 (Fujifilm Medical), respectively. The imaging cassettes used were Fuji IP cassettes type CC (Fujifilm Medical). The angles, which were the evaluation indices in this study, were measured with Synapse software packages with the 3D workstation ZIO station 610 (AMIN, Tokyo, Japan) on the image display device EIZO Flexscan S2100 (EIZO, Ishikawa, Japan). We used a tilt-angle measurement device (Daiso, Hiroshima, Japan).

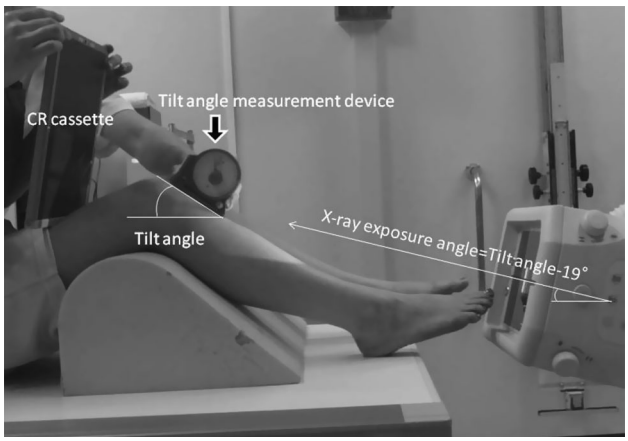

Fig. 1 Clinical image of measurements obtained with an inclinometer. Imaging involved maintaining 60° knee flexion and with use of an inclinometer to set the incident X-ray angle at 19° to the reference line connecting the anterior border of the patella and the tibial tuberosity

2.2 Patellar axial positioning error

For measuring the patellar axial positioning error, the point C on the superior border of the patella, the point O on the inferior border of the patella, and the point C′ (femur) were first defined on the line perpendicular to the line, the point A on the center border of the patella, and the point B on lateral end of the patella. The patellar axial positioning error was defined by the ratio of the distance CO to the distance CC′ (Fig. 2). CO gets closer to zero as AB becomes almost tangential to the articular surface of the patella. Student's t test was employed in the statistical analysis for the patellar axial positioning error. A p value of <0.05 was considered to indicate a statistically significant difference.

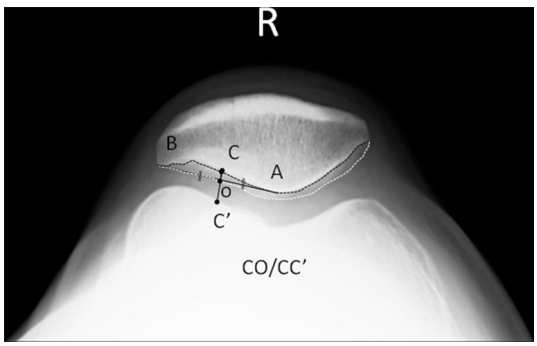

Fig. 2 Measurement of the patellar axial positioning error with use of the CO/CC′ ratio. The line linking C (*superior patellar margin*), O (*inferior patellar margin*), and femur (C') that directly intercepts the center of A (*center border of the patella*) to B (*lateral end of the patella*) line was measured with an accuracy of 0.1 mm, after which the CO/CC′ ratio was calculated

3 Results

The relative errors according to the patellar tilt were determined from each of the axial images of the patella of the same patients obtained with use of the conventional and new techniques for the radiographic diagnosis of knee-joint disease. The patellar axial positioning error was 0.40 with the conventional technique, whereas that with the new technique was significantly different at 0.30 ($p < 0.001$) (Fig. 3).

4 Discussion

In this clinical study, compared with the conventional technique, the patellar axial positioning error decreased from 0.40 to 0.30 ($p < 0.001$) with the new technique. This result indicated that the precision of axial imaging increased with the new technique. However, in some cases, the tibial tuberosity overlapped the patellofemoral-joint space. This might be due to traction stress caused by weakness of the quadriceps tendon, which affects the tissue of the patellar ligament. This sometimes occurred in patients who had a narrowed patellofemoral-joint space or a patella infera. Because our study included elderly patients who were undergoing regular follow-up examinations, many had degenerative knee diseases.

Taking these factors into consideration, it could be said that the study was conducted under very strict conditions for evaluation of the clinical usefulness of the new skyline-view imaging technique as a standard technique. Patients with knee-joint disorders generally undergo follow-up examinations once or twice a year. To evaluate the usefulness of the new technique regarding reproducibility, we selected postoperative partial-knee-replacement patients because they undergo the same type of imaging repeatedly within a short period of time. The knee-replacement patients included in the study underwent postoperative knee imaging eight times by different radiologic technologists. In the patients who underwent imaging three times with the conventional technique, the patellar axial positioning error was 0.34, standard deviation (SD) 0.10. In the patients who underwent imaging five times with the new technique (Fig. 4), the patellar axial positioning error was 0.08 (SD 0.02). These results indicated that the reproducibility tended to be improved by use of the new technique.

The incident X-ray angle was 19° to the line between the anterior border of the patella and the tibial tuberosity, and was independent of the flexion angle. The fixed points of the anterior border of the patella and the tibial tuberosity made consistent repetition of imaging possible, and we believe that this could also be effective for imaging in cases of patellar dislocation. Other advantages of the new

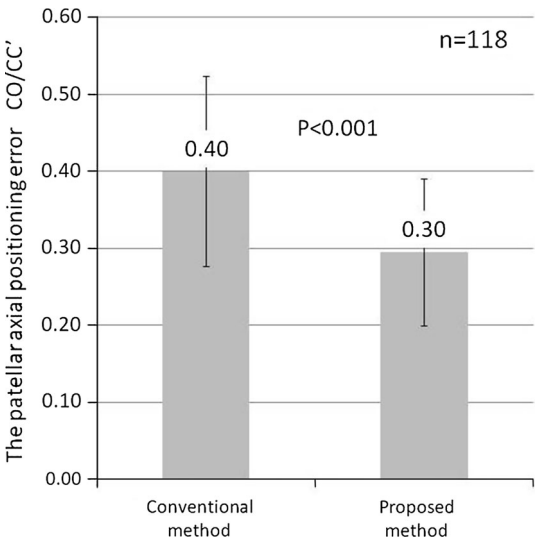

Fig. 3 Results of patellar positioning error calculation ($n = 118$). The CO/CC′ ratio decreased with the new imaging technique (0.30) compared with the conventional imaging technique (0.40) ($p < 0.001$)

Fig. 4 Reproducibility of image for the same patients with use of the new skyline-view imaging technique (most recent two measurements shown). **a** CO/CC′ = 0.066, **b** CO/CC′ = 0.065. Reproducibility results of the last five imaging sessions conducted for postoperative follow-up examination indicated a CO/CC′ ratio of 0.08 (SD 0.02). These results indicated that reproducibility was better with the new technique

technique include the following: (a) the increased positioning freedom makes it possible to perform imaging in standing load-bearing [6] and non-load-bearing positions, and (b) imaging can be performed with the patient in the position closest to that in which they experience pain.

The reproducibility of our technique needs to be evaluated further by data obtained from more patients.

5 Conclusions

This clinical study confirmed that the new skyline-view imaging technique, which uses the anterior border of the patella and the tibial tuberosity as position markers that can be confirmed by palpation, provides more accurate axial images than the conventional imaging technique.

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Conflict of interest This paper has neither been published nor is it under consideration for publication elsewhere. All authors have contributed to the work described in the paper, and they report no conflict of interest.

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