

## **Subluxation of the patella\***

### **Investigation by computerized tomography**

**T. Sasaki and T. Yagi**

Department of Orthopaedic Surgery, School of Medicine, Hokkaido University

**Summary.** *Subluxation of the patella may produce pain and instability in young people. However its classification, diagnosis and treatment are controversial. We have used computerized tomography (CT) to measure the amount of lateral shift of the patella and the angle of tilt to the femur in patients with subluxation. The mean lateral shift was 31.4% and the angle of tilt 31.8 degrees. These values are significantly greater than those obtained from conventional axial radiographs or in arthrographic axial views.*

*We have obtained interesting evidence that the rate of lateral shift apparently increased on voluntary contraction of the quadriceps muscle (Q-contracted). With the quadriceps contracted, the mean rate of the lateral shift in the affected knees showed a significant increase (+27.7%) compared to that in normal knees (+14.0%).*

*We have reviewed 40 knees treated by operative realignment with a mean follow-up of 27 months. The mean rates of lateral shift measured from CT-image in the knees before operation improved significantly to the normal range at follow-up, both with the quadriceps relaxed and contracted. The results evaluated by Insall's criteria were "excellent" in 13 knees; "good" in 22; "fair" in 3 and "poor" in 2. The satisfactory group (those with excellent and good results) revealed an improvement in lateral shift when the quadriceps was contracted, while the unsatisfactory group (fair and poor results) did not.*

**Résumé.** *La subluxation de la rotule peut entraîner chez les sujets jeunes des douleurs et une instabilité. Cependant, la classification, les critères du diagnostic et le traitement sont sujets à controverse. Nous avons utilisé la tomodensitométrie (TDM) pour mesurer l'importance du déplacement externe de la rotule et son inclinaison par rapport au fémur dans un groupe de malades présentant une subluxation. La déviation moyenne était de 31,4% et l'angle d'inclinaison de 31,8 degrés. Ces chiffres étaient significativement plus élevés que ceux obtenus à partir de radiographies conventionnelles ou d'arthrographies axiales.*

*Nous avons montré que le déplacement externe de la rotule augmente lors de la contraction volontaire du quadriceps. Lorsque le quadriceps est contracté, la déviation augmente de 27,7% sur les rotules subluxées contre 14% dans les genoux normaux.*

*Nous avons revu 40 genoux traités par une opération de réalignement, avec un recul moyen de 27 mois. Le taux moyen de déviation externe, mesuré par TDM, s'est amélioré significativement jusqu'à des chiffres normaux, que le quadriceps soit relâché ou contracté. Les résultats, évalués selon les critères d'Insall, sont «excellents» pour 13 genoux, «bons» pour 22, «assez bons» pour 3 et «mauvais» pour 2. Le groupe des résultats satisfaisants (excellents et bons) présente une diminution du déplacement de la rotule même lors de la contraction du quadriceps, contrairement au groupe des résultats «assez bons» et «mauvais».*

**Key words:** *Patella, Subluxation, Computerized tomography*

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Address offprint requests to: T. Sasaki, School of Medicine, University of Hokkaido, Kita-15 Nishi-7, Kita-ku, Sapporo 060, Japan.

Malalignment of the patella includes a group of conditions such as subluxation and lateral patellar tracking, and is often accompanied by chondromalacia patellae. It has been reported as the "recurrent subluxation syndrome" by Trillat and Mori [9, 16], the "patellar compression syndrome" by Ficat and Hungerford [5, 12] and "quadriceps dysplasia" by Fox [6].

Various radiographical techniques for evaluating the anatomical abnormalities in the patellae of patients with those conditions have been reported, but there is no accurate and simple method [15]. In the past few years whole-body computerized tomography (CT) has become available, allowing the observation of transverse images, and is increasingly applied to orthopaedic diseases. We have been using CT for the measurement of leg alignment and have reported pathological conditions of the foot and the knee joint [20, 21]. Computerized tomography allows observation of the knee joint in the fully extended position, and therefore makes it possible to observe the patellofemoral joint when the patella is at its most unstable.

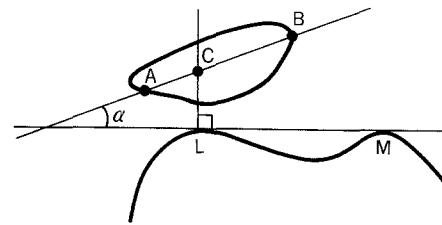
The purposes of this study were to develop a method of determining the parameters of patients with subluxation of the patella on the basis of CT-images, and to evaluate the effects of surgical treatment by means of this method.

## Materials and methods

### *Development of a method for investigating the patellofemoral joint by CT and evaluation of its usefulness*

CT-images of the patellofemoral joint, having a slice width of 5 mm at 1 cm intervals, were taken at four sites with the knee fully extended in the supine position using a Toshiba TCT-60A. The CT-images were obtained in two ways, with the quadriceps muscle relaxed (Q-relaxed) or contracted (Q-contracted). We investigated 20 patients (24 knees) with subluxation of the patella (Group 1). Their ages ranged from 13–29 years, with a mean of 20 years. These knees exhibited lateral deviation of the patella on axial projection radiography. The patients had subjective symptoms, such as pain originating from the patellofemoral joint and giving way. The clinical findings included tenderness of the joint space, crepitation, hypermobility of the patella and the apprehension sign. As controls, 24 knees of 12 female subjects of almost the same age, but who had no subjective symptoms or objective findings and showed no malposition of the patella on axial radiography, were investigated.

Assuming that the part of the patella which shows the largest sectional area is its centre, the lateral shift (measured as a percentage) and the tilting angle (in degrees) of the patella against the femur were measured from the CT-images (Fig. 1). In the same patients in the supine position, conventional axial radiographs and arthrograms in 30 degrees of flexion were obtained, and the lateral shift and the tilting angle were measured.



**Fig. 1.** Methods for measuring lateral shift (as a percentage) and tilting angle (in degrees) from the CT-image at the middle part of the patella. A: Lateral edge of the facet, B: Medial edge of the facet, L: Highest point of the lateral condyle, M: Highest point of the medial condyle, C: Crossing of the transverse patellar line (AB) and the perpendicular line from L. Lateral Shift =  $\frac{AC}{BC} \times 100$  (%) Tilting angle =  $\alpha$  degrees

The following comparisons were made using the values thus obtained. First, values obtained by the three different methods were compared in the patients with symptoms. Second, values obtained from the CT-images (with the quadriceps relaxed and contracted) were compared in the patients with symptoms and in the control group.

### *Evaluation of the effects of surgical treatment in terms of CT values*

Patients with subluxation of the patella who did not respond to 6 months' conservative treatment, such as quadriceps exercise, medicinal treatment and the use of the dynamic patellar brace developed by Palumbo [18], were treated by lateral retinacular release, medial reefing and transfer of the vastus medialis muscle [8]. For distal realignment medial transfer of a part of the patellar tendon [4] was used for patients who were still growing, and medial transfer of the tibial tubercle [3] for those who had stopped growing. Proximal realignment alone was employed when the Q-angle was less than 20 degrees, and proximal realignment in combination with distal realignment when the Q-angle was more than 20 degrees.

Forty-six knees in 41 patients with subluxation of the patella were operated on in our clinic between 1978 and 1984. Thirty-five of these patients, comprising one male and 34 females and involving 40 knees (Group 2), were followed up for at least 12 months and at most 52 months, with an average of

**Table 1.** The assessment of patella-function as described by Insall

Excellent:	patients who had forgotten about the knee, had no complaints, pain, or instability, and had normal function, including return to sports
Good:	patients who had mild pain, no instability, and normal function
Fair:	patients who had moderate pain, a feeling of insecurity due to occasional instability, mildly limited function, and partial improvement of preoperative condition
Poor:	patients who had moderate to severe pain and instability (including redislocation) that limited function significantly: the operation neither improved nor worsened the condition

27 months. Proximal realignment was performed on 6 knees and combined realignment (proximal and distal) on 24.

CT-images were obtained of 35 knees before operation and in 30 knees after operation. The lateral shift and the tilting angle were measured from these images to evaluate the degree of improvement in the lateral deviation of the patella after operation. The clinical results were then evaluated according to the subjective criteria described by Insall et al. [10] (Table 1). Finally, the relationship between the degree of improvement in the lateral deviation of the patella and the clinical results was investigated.

The results were statistically analysed by the Chi-square test.

## Results

### Evaluation of the usefulness of CT for investigating the patellofemoral joint in Group 1 patients

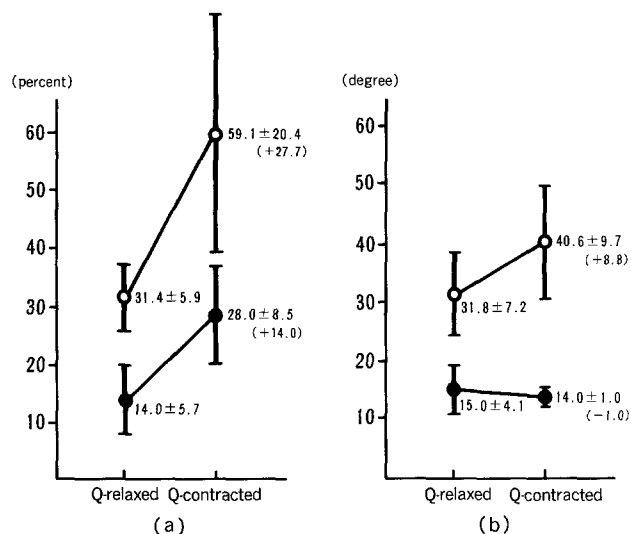
- The results of measurement by three different methods in the group with symptoms were compared. The position of the patella on axial view radiographs was expressed as a mean lateral shift of  $12.1 \pm 3.2\%$  and a mean tilting angle of  $17.2 \pm 2.9$  degrees. The mean values obtained from the arthrographic axial views were  $18.9 \pm 4.0\%$  for the lateral shift and  $19.8 \pm 3.3$  degrees for the tilting angle. In the CT scan with the quadriceps relaxed, the mean lateral shift was  $31.4 \pm 5.9\%$  and the mean tilting angle was  $31.8 \pm 7.2$  degrees. Both mean values obtained from CT scans were significantly greater than those obtained from the above two methods ( $P < 0.01$ ) (Table 2). More precise images of the patellar malposition were obtained by CT compared with those in conventional or arthrographic axial views.
- A comparison of values obtained from CT scans with the quadriceps relaxed and contracted was made between the knees with symptoms and the control group. The mean lateral shift in

**Table 2.** Comparison of values measured from three different methods in subluxation of the patella (N: 20 knees)

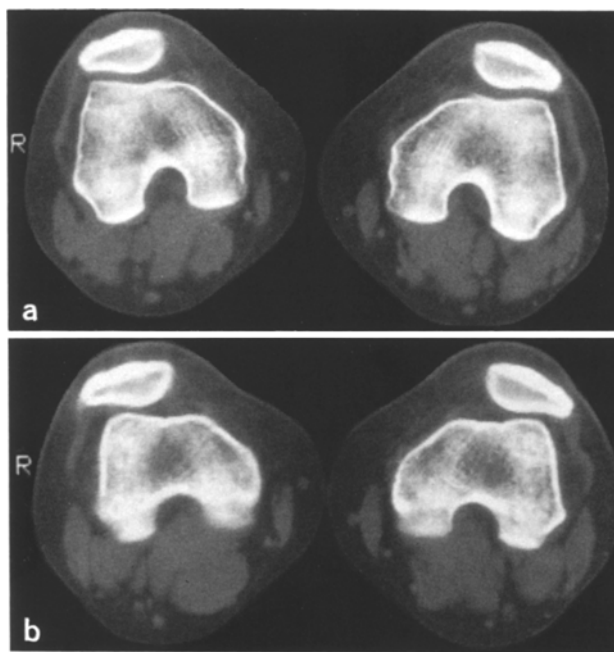
	Conventional axial view	Arthrographic axial view	CT image (Q-relaxed)
Lateral shift (percentage)	$12.1 \pm 3.2$	$18.9 \pm 4.0$	$31.4 \pm 5.9$
Tilting angle (degree)	$17.2 \pm 2.9$	$19.8 \pm 3.3$	$31.8 \pm 7.2$

The values indicate mean  $\pm$ SD. The Chi-square test was used to test for significance between the two methods.

There were significant differences between the value of the CT-image and that of the arthrographic axial view ( $P < 0.01$ ), and also between the value of CT-image and that of conventional axial view ( $P < 0.01$ ) in both the lateral shift and the tilting angle



**Fig. 2a and b.** The mean values ( $\pm$ S.D.) of lateral shift **a** and tilting angle **b** measured from the CT-image in the symptomatic knee group (open circle plot,  $n=24$ ) and in the normal knee group (solid plot,  $n=24$ ). The figure in parenthesis represents the rate of increase when the quadriceps was contracted



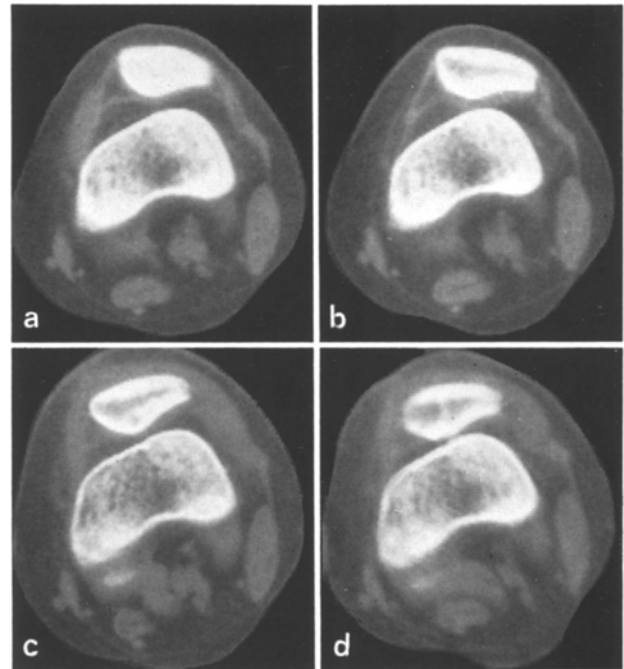
**Fig. 3a and b.** CT-image of a case with bilateral subluxation of the patella. With the quadriceps relaxed **a**, the patella is slightly deviated from its normal position, while when the quadriceps is contracted **b** the patella shifts significantly and tilts laterally

the knees with symptoms was  $31.4 \pm 5.9\%$  with the quadriceps relaxed and  $59.1 \pm 20.4\%$  with the quadriceps contracted, showing an increase of 27.7% with the contraction of the quadriceps muscle. The corresponding values in the control

group were  $14.0 \pm 5.7\%$  with the quadriceps relaxed and  $28.0 \pm 8.5\%$  with the quadriceps contracted, showing only a slight increase of 14%. The values for the lateral shift with the quadriceps relaxed and contracted, and the rate of increase, were all significantly greater in the group with symptoms than in the controls ( $P < 0.01$ ) (Fig. 2a). Similarly, the values of the tilting angle with the quadriceps relaxed and contracted, and the rate of increase, were also significantly greater in the group with symptoms than in the controls ( $P < 0.01$ ) (Fig. 2b). Therefore, malposition of the patella was reflected more clearly when the quadriceps is contracted (Fig. 3a, b).

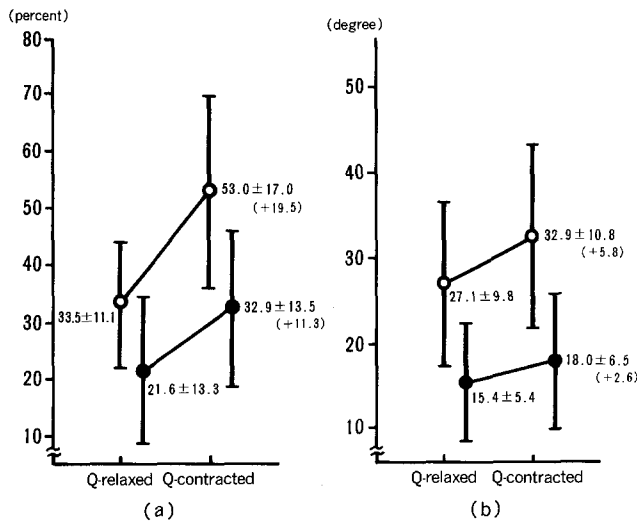
*Evaluation of the effects of surgical treatment in Group 2 patients*

The preoperative lateral shift was  $33.5 \pm 11.1\%$  with the quadriceps relaxed and  $53.0 \pm 17.0\%$  with the quadriceps contracted. At follow-up after operation, the corresponding values were: with the quadriceps relaxed  $21.6 \pm 13.3\%$ , and  $32.9 \pm 13.5\%$  with the quadriceps contracted. Those two parameters obtained during the follow-up period were similar to those in the controls (Fig. 4a). On the other hand, the preoperative tilting angle was  $27.1 \pm 9.8$  degrees with the quadriceps relaxed and  $32.9 \pm 10.8$  degrees with the quadriceps contract-



**Fig. 5a-d.** Preoperative and follow-up CT-image in a case of subluxation of the patella.

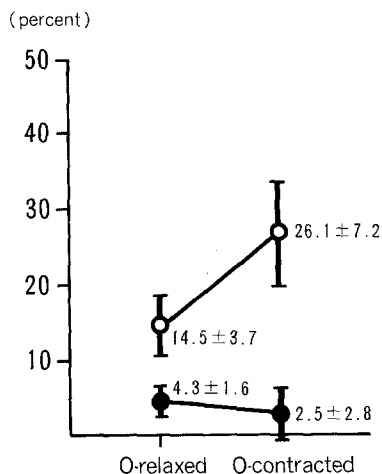
The preoperative values were as follows: **a** 31.6% in lateral shift with the quadriceps relaxed; **b** 63.6% in lateral shift with the quadriceps contracted. **a** 32 degrees in the tilting angle with the quadriceps relaxed; **b** 40 degrees in the tilting angle with the quadriceps contracted. The follow-up values were: **c** 20.7% in lateral shift with the quadriceps relaxed; **d** 22.7% in lateral shift with the quadriceps contracted; **c** 11 degrees in the tilting angle with the quadriceps relaxed; and **d** 20 degrees in the tilting angle with the quadriceps contracted



**Fig. 4a and b.** The mean values ( $\pm$ S.D.) of lateral shift **a** and tilting angle **b** in preoperative (open circle plot,  $n=35$ ) and follow up (solid plot,  $n=30$ ) patients of Group 2. The preoperative lateral shift of the patella improved to an almost normal range in both with the quadriceps relaxed and contracted following operation. The preoperative tilting angle was also decreased at follow-up. However, these values are little greater than normal

ed, whereas the values during the follow-up period were  $15.4 \pm 5.4$  degrees with the quadriceps relaxed and  $18.0 \pm 6.5$  degrees with the quadriceps contracted. Although those two parameters were significantly improved after operation ( $P < 0.01$ ) they were still higher than those in the control group (Fig. 4b) (Fig. 5a, b, c, d).

The postoperative conditions were evaluated according to Insall's criteria as "excellent" in 13 knees, "good" in 22, "fair" in 3 and "poor" in 2. The knees with the excellent and good results were considered satisfactory (35 knees) and those with fair and poor results as unsatisfactory (5 knees). The relationship was determined between the clinical results and the amount of postoperative improvement in the lateral deviation of the patella. In the satisfactory group, the lateral shift was  $14.5 \pm 3.7\%$  with the quadriceps relaxed and  $26.1 \pm 7.2\%$  with the quadriceps contracted, while in the unsatisfactory group it was  $4.3 \pm 1.6\%$  with the quadriceps relaxed and  $2.5 \pm 2.8\%$  with the quadriceps contracted (Fig. 6).



**Fig. 6.** The degree of improvement in patellar deviation by operative realignment. The lateral shift in the satisfactory group (*open circle plot*,  $n=35$ ) showed improvement with the quadriceps contracted, while in the unsatisfactory group (*solid plot*,  $n=5$ ) it showed less improvement both with the quadriceps relaxed and contracted

## Discussion

Merchant [15], Hughston [9], Laurin [14] and Aglietti [1] have reported that malposition of the patella of patients with subluxation can be evaluated by axial radiography. Fukabayashi [7] observed the knee by axial radiography in 45 degrees of flexion and pointed out that the patella was shifted and tilted laterally, with a lateral shift of  $34.0 \pm 20.0$  degrees (normal control  $4.0 \pm 2.4\%$ ) and a tilting angle of  $30.0 \pm 8.6$  degrees (normal control  $4.0 \pm 3.7$  degrees). Mori [16] reported a lateral shift of  $22.4 \pm 13.0\%$  and a tilting angle of 24.5 degrees obtained by axial radiography in 60 degrees of flexion. In comparison with these values, the knees of our Group 1 patients showed low values for the lateral shift ( $12.1 \pm 3.2\%$ ) and the tilting angle ( $17.2 \pm 2.9$  degrees) on radiography in 30 degrees of flexion. This difference is probably attributable to the difference in the pathological conditions of the various patients and the differences in the angle of flexion of the knee during radiography. Our patients did not include those with permanent dislocation and subluxation of the patella or recurrent dislocation of the patella. In cases of recurrent dislocation of the patella, lateral deviation tends to increase with increase in flexion of the knee. By contrast, the characteristic feature seen in the radiographs of our cases was a lateral deviation of the patella which gradually transferred to the midline with increased flexion during axial radiography.

The nearer the angle of the knee approaches to full extension, the more unstable the patella be-

comes, so that it moves proximally and becomes dislocated from the patellar groove. However, conventional axial radiography is carried out in 20–30 degrees of flexion. CT allows imaging at lesser angles of flexion and has the advantage that there is no overlapping of images. Furthermore, CT allows measurement of the knee joint at full extension while the quadriceps muscle is contracted. In our Group 1 cases, the lateral shift and the tilting angle were increased by 27.7% and 8.8 degrees respectively due to contraction of the quadriceps muscle. This method is valuable because it allows a more accurate understanding of the pathological state of the subluxation of the patella by observing the effects of contracting the quadriceps muscle.

Ficat and Bandi et al. [2, 8] recommend axial radiography of the patellofemoral joint while load-bearing, but this method is not perfect because of the difficulty in positioning the leg accurately, the incident angle of X-rays and poor definition. If the quadriceps is contracted during CT-imaging, this substitutes for the tension of the quadriceps muscle during load-bearing. Some authors emphasize the need for CT-images of the knee in semiflexion, but our research revealed that the values obtained in the fully extended knee correlate well with those in the semiflexed knee, and that the condition is reflected by the greater values. Thus, it is useful to determine the values of the parameters in the extended position of the knee.

The results of operation by our methods revealed that 35 (88%) of 40 knees showed satisfactory results. In this group, the rate of improvement in the lateral shift when the quadriceps was contracted was high. The group with unsatisfactory results showed almost no improvement in the lateral deviation of the patella. However, in one case with a poor result, severe pain was present despite improvement of the patellar deviation. When this patient was examined by arthroscopy, marked chondromalacia patellae was found. Therefore, simultaneous intraarticular operation, such as shaving and drilling, should be added to realignment of the patella if marked chondromalacia is present [11, 17] in order to obtain even better results.

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