Purpose: The aim of this study was to investigate the pathoanatomic features of patellar instability by arthroscopically comparing patellofemoral congruence with rotation of the knee joint and/or electrical stimulation of the quadriceps (ESQ) between knees with and without patellar instability. Methods: We retrospectively examined 83 knee joints in 83 patients. The joints were classified into 2 groups: group 1 comprised those without a history of patellar dislocation and included 59 patients (25 male and 34 female patients), and group 2 comprised those with a history of patellar dislocation and included 24 patients (9 male and 15 female patients). Evaluation of patellofemoral congruence at 30° of flexion of the knee joint was conducted based on an axial radiograph and arthroscopic findings. The congruence angle was measured on the radiograph. The position of the patellar central ridge (PPCR) on the trochlear groove during arthroscopy was measured using still video frames of knee joints with rotational stress and/or ESQ. Statistical differences in the measurements between the 2 groups were assessed with the unpaired t test and the area under the receiver operating characteristic curve of each measurement. Results: There were significant differences ($P < .0001$) between the 2 groups in the congruence angle on radiographs and PPCR in knee joints with rotational stress and/or ESQ on arthroscopy. External and internal rotation of the knee joint caused lateral and medial patellar shift, respectively, in both groups, but the shift was significantly larger in group 2. ESQ in addition to rotation caused further patellar shift in group 2 but reduced patellar shift in group 1. Measurement of PPCR with external rotation of the knee and ESQ was the only method to show an area under the receiver operating characteristic curve of 1. Conclusions: There were significant differences in the effects of rotation of the knee joint and/or ESQ on patellofemoral congruence at 30° of flexion of the knee joint on arthroscopy between knees with and without patellar instability. Level of Evidence: Level III, diagnostic study of nonconsecutive patients.

Patellofemoral congruence is usually diagnosed based on axial radiographs of slightly flexed knee joints. There have been many reports about how to take such radiographs and how to measure them, including the congruence angle, lateral patellofemoral angle, and lateral patellar displacement. Although these measurements determined a cutoff value that differentiates joints with patellar maltracking from normal knee joints, the discrepancies between the results of radiographic measurements and clinical symptoms have not been fully addressed. Therefore evaluation of patellofemoral alignment using rotational stress of knee joints on radiographs, kinematics on computed tomography or magnetic resonance (MR) images, and patellar tracking on arthroscopy have been reported as methods to differentiate more precisely between knees with and without patellar maltracking. The addition of contraction of the quadriceps to these methods may make differentiation clearer. Recently, several reports have been published examining electrical stimulation of the quadriceps (ESQ) to simulate natural patellar tracking during surgery. However, no quantitative assessment of patellofemoral congruence with slight flexion of the knee during arthroscopy has been reported.

The aim of this study was to investigate the pathoanatomic features of patellar instability by arthroscopically comparing patellofemoral congruence with rotation of the knee joint and/or ESQ between knees with and without patellar instability. Our hypothesis
was that significant differences would exist in the effects of rotation of the knee joint and/or ESQ on patellofemoral congruence between these 2 conditions.

**Methods**

Institutional review board approval was obtained for this study. To be included in this retrospective study, the following criteria had to be met: (1) patients visited our knee joint clinic between April 2009 and November 2012, (2) they were aged younger than 50 years, and (3) they underwent arthroscopic examination that was performed under general anesthesia without muscle relaxants after radiographs and MR images of the knee joint had been taken. Knee joints with habitual or permanent dislocation of the patella, anteroposterior or varus-valgus instability, previous operations, tumors, contracture, scar tissue around the patella, or osteoarthritis of grade 2 or higher on the Kellgren-Lawrence grading system on radiographic examination were excluded from this study.

**Patients**

All patients who were indicated for arthroscopic examination between April 2009 and November 2012 and who did not meet the exclusion criteria (114 patients in total) underwent arthroscopic evaluation of patellofemoral congruence. Of these patients, 18 were excluded from this study because a different method of anesthesia was used, the patellar central ridge or trochlear groove was not recognized because of deformity of the bone tissue, or not all areas of the trochlear groove were seen because of synovial hypertrophy. Of the remaining 96 patients, 13 were excluded because they were aged 50 years or older. Consequently, 83 knee joints in 83 patients were included in this study. They were classified into 2 groups. Group 1 comprised joints with no history of patellar dislocation. This group included 59 patients (25 male and 34 female patients), ranging in age from 12 to 49 years (mean, 29.4 years). The diagnoses of the affected knee joints based on clinical, MR imaging, and arthroscopic findings included the following: medial meniscal tear (15 joints), lateral meniscal tear (5 joints), lateral discoid meniscal tear (11 joints), recurrent subluxation of the lateral meniscus (9 joints), tibiofemoral chondral lesion (11 joints), and slight synovitis (8 joints). Group 2 comprised joints with a history of patellar dislocation. This group included 24 patients (9 male and 15 female patients), ranging in age from 13 to 49 years (mean, 26.8 years). Group 2 included 20 cases of recurrent dislocation of the patella and 4 cases with their first occurrence of patellar dislocation. Recurrent dislocation of the patella refers to a patellar dislocation that has occurred more than once, whereas habitual patellar dislocation refers to patellar dislocation that occurs every time the knee is flexed. The distribution of the knee joints by group and sex, as well as the mean age in the subgroups classified by group and sex, is shown in Table 1.

**Method for Obtaining Axial Radiograph and Assessment of Patellofemoral Congruence**

With the patient in the supine position, an axial radiograph was taken using the method of Laurin et al. but with the knee joint flexed 30°. The congruence angle was measured on the radiograph using the original method by the same orthopaedist, who did not know the patient’s name or diagnosis (Fig 1).

**Arthroscopy With Rotation of Knee Joint and/or ESQ**

General anesthesia was administered to all patients with a laryngeal mask airway. The pneumatic tourniquet was not inflated during arthroscopic examination of the patellofemoral joint. Lactated Ringer solution

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**Table 1. Patient Data**

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of knee joints</td>
<td>59</td>
<td>24</td>
<td>$&gt;.81^*$</td>
</tr>
<tr>
<td>Male</td>
<td>25</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>34</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Age (mean ± SD) (yr)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>31.0 ± 12.1</td>
<td>26.6 ± 10.1</td>
<td>.33</td>
</tr>
<tr>
<td>Female</td>
<td>28.2 ± 13.9</td>
<td>26.9 ± 18.1</td>
<td>.78</td>
</tr>
<tr>
<td>Total</td>
<td>29.4 ± 13.1</td>
<td>26.8 ± 15.3</td>
<td>.43</td>
</tr>
</tbody>
</table>

*Fisher exact test.

---

**Fig 1.** Drawing showing how we measured the congruence angle on radiographs. The angle created by the highest point of the medial femoral condyle (M), the deepest point of the trochlear groove (D), and the highest point of the lateral femoral condyle (L) is the sulcus angle. L1 is the line bisecting the sulcus angle. L2 is the line connecting the central ridge of the patella (C) and D. The angle created by L1 and L2 is the congruence angle. The congruence angle is positive when L2 is located lateral to L1 and negative when L2 is located medial to L1.
was used for irrigation of the joint with a pressure of 20 mm Hg. Examination of the patellofemoral alignment was performed through a proximal superomedial portal19 with the knee joint flexed 30° with the use of a 30°, 45°, or 70° angled arthroscope with a 105° view angle and a video system (1188 High Definition: Stryker Endoscopy, San Jose, CA), which permitted observation of the entire trochlear groove in a visual range from the central proximal portion of the patellofemoral joint. First, a 45° angled arthroscope was used in each patient. When the entire trochlear groove was not observed in a visual range with the 45° angled arthroscope, a 70° angled arthroscope was used to locate the tip of the arthroscope further from the patellofemoral joint instead of making another portal on a more proximal portion of the thigh. On the other hand, when the image of the patellofemoral joint was too small with the 45° angled arthroscope, a 30° angled arthroscope was used to locate the tip of the arthroscope more closely to the patellofemoral joint instead of making another portal on a more distal portion of the thigh. The 30°, 45°, and 70° angled arthroscopes were used for 7, 40, and 12 cases, respectively, in group 1 and 4, 14, and 6 cases, respectively, in group 2. Irrigation solution was drained through an anteromedial portal by use of an outflow tube.

The rotational positions of the knee joint during observation of patellofemoral congruence were neutral, external, and internal. When external or internal rotation was applied to the knee joint, an assistant standing by the side of the examined leg held the patient’s foot and rotated the leg by hand externally or internally to the maximum. Rotation of the knee joints of all patients was performed by the same assistant and the same operator. When an examined knee joint was rotated and to which direction were recorded by a video camera on a tripod located overhead of the patient. The video was transported into a small window on the arthroscopic display in real time (picture-in-picture) using a multiformat converter (XC1 series; Digitalarts Ltd, Tokyo, Japan) or SDC Ultra system (Stryker Endoscopy), and the findings of arthroscopy and the video were recorded simultaneously.

ESQ was performed with an electrical muscle stimulator (PH-M1010; Nihon Medix, Chiba, Japan). A self-adhesive flexible thin gel pad, 70 × 90 mm in size, was used as a proximal electrode and was attached longitudinally to the skin over the rectus femoris muscle about 10 cm distal from the anterior superior iliac spine to the patella, which did not interfere with application of the tourniquet. A 23-gauge Cattelan needle (TOP Corp, Tokyo, Japan) was used as the distal electrode and was introduced into the center of the tendon of the rectus femoris muscle about 2 cm proximal from the patella. An electrical current was applied as a biphasic sine curve of 50 Hz. The maximum current that did not elevate the crus against gravity was used to stimulate the quadriceps and was usually 20 to 30 mA. A pilot study was performed before the current study to determine how the location of the distal electrode influences the position of the patella during ESQ. We confirmed that displacement of the patella on arthroscopy caused by ESQ with and without rotation of the knee joint was not influenced by 1-cm displacement of the distal electrode in any direction from the original position.

### Arthroscopic Evaluation of Patellofemoral Congruence

An image of the patellofemoral joint including the entire area of the trochlear groove was captured from videos obtained during arthroscopy. The still frame was trimmed into a square that was inscribed with a round image from arthroscopy. Then, image distortion of the still frame was corrected by use of software (Adobe Photoshop Elements 2.0; Adobe Systems, San Jose, CA), in which “spherical surface” was selected from a pull-down menu.

In our preliminary study, images of graph paper were taken vertically in a container filled with lactated Ringer solution with the 30°, 45°, and 70° angled arthroscopes used in this study. The distortion of the obtained images was calculated by comparing the same length on the graph paper from the central portion of the round image with that from the peripheral portion. The distortion was a maximum of 36% before distortion correction. The percentage of “spherical surface” in the software program that was most suitable for correcting the distortion was then determined by trial and error. Selecting −28% in the software program was most suitable for correcting the distortion of images of the 30° angled arthroscope, −30% was most suitable for the 45° angled arthroscope, and −33% was most suitable for the 70° angled arthroscope. The distortion became less than 1% after the correction. However, the marginal 3% of the original arthroscopic image was not sufficiently corrected using the software.

Measurement of the axial linear patellar displacement on radiographs was modified and used for arthroscopic evaluation of the patellofemoral alignment. The axial linear patellar displacement was originally reported in millimeters.20 In this study, however, the position of the patellar central ridge (PPCR) on the trochlear groove was measured as a percentage of the axial linear patellar displacement to the width of the lateral portion of the trochlear groove on arthroscopy to eliminate the influence of the magnification of images. All measurements were performed by the same orthopaedist, who did not know the patient’s name or diagnosis. On the corrected still frame, the tangent touching the medial and lateral articular surfaces of both sides of the trochlear groove was assumed to be the x-axis (Fig 2). The point on the trochlear groove
that was the furthest from the x-axis was considered to be the deepest point. The intersection of the x-axis and the line that met the x-axis at a right angle and passed through the deepest point was assumed to be 0 on the x-coordinate. The lateral point of tangency was assumed to be 100. The intersection between the x-axis and the line that was perpendicular to the x-axis and passed through the patellar central ridge was designated as P, and the position of P was measured as PPCR on the x-coordinate.

Measured PPCR without ESQ was designated as Po, whereas that with ESQ was designated as Ps. Measured PPCR with neutral rotation of the knee joint without and with ESQ was designated as PoN and PsN, respectively; that in external rotation was designated as PoE and PsE, respectively; and that in internal rotation was designated as PoI and PsI, respectively. The effects of external and internal rotation of the knee joint on PPCR were calculated as PoE — PoN and PoI — PoN, respectively. The effects of ESQ during neutral, external, and internal rotation were calculated as PsN — PoN, PsE — PoE, and PsI — PoI, respectively.

**Statistical Analysis**

All statistical analyses were performed with IBM SPSS Statistics (version 20.0; IBM, Armonk, NY) with a significance level of .05. Intraobserver and interobserver reliabilities with respect to the congruence angle and PoN were estimated as follows. For the former, the congruence angle and PoN of all knee joints were measured twice by the same examiner, with a minimum interval of 1 month between measurements, and the intraclass correlation coefficient was obtained for each value. For the latter, 2 examiners measured the congruence angle and PoN of all knee joints, and the intraclass correlation coefficient was obtained for each value. The correlation between the congruence angle and PoN was also determined.

The Fisher exact test was used for statistical analysis of the distribution of the knee joints by sex between the 2 groups, and the unpaired $t$ test was used for statistical analysis of the mean age between the 2 groups. The significance of differences in the results for the congruence angle, Po, and Ps between the sexes in each group was determined with the unpaired $t$ test. When the effects of rotation of the knee joint or ESQ were studied, the significance of differences in the mean values between before and after rotation or ESQ was determined with repeated-measures analysis of variance. Furthermore, the significance of differences between the 2 groups in the results for the congruence angle, Po, and Ps and the effects of rotation of the knee joint and ESQ was determined with the unpaired $t$ test.

A receiver operating characteristic curve was drawn for each measurement and effect of rotation and ESQ, and the area under the receiver operating characteristic curve (AUC) of each measurement and effect was studied.

![Fig 2](image-url)
Results

The intraclass correlation coefficients for intraobserver reliability analysis of the congruence angle and PoN were 0.94 and 0.93, respectively. Those for interobserver reliability analysis of the congruence angle and PoN were 0.89 and 0.87, respectively. The correlation coefficient between the congruence angle and PoN was 0.82.

No significant difference was observed in the distribution of the knee joints by sex or in the mean values of age between the 2 groups (Table 1). The results of measurements of the congruence angle, PoN, PoE, PoI, PSN, PsE, and PsI; effects of rotation of the knee joint; and effects of ESQ in each group are shown in Table 2.

Congruence Angle on Radiographs

Radiographic examination showed that the mean value of the congruence angle in group 2 was significantly higher than that in group 1 ($P < .0001$). No significant difference between the sexes was seen in the angle in either group.

PPCR on Arthroscopy

In group 1 the mean PoN value of female patients was significantly higher than that of male patients by 3.6% ($P = .029$). No other significant differences were noted in the other measurement results of PPCR between the sexes. The PoN value was about 5%, indicating that PPCR was located close to the deepest point of the trochlear groove. PPCR was shifted laterally by about 9% ($P < .0001$) with external rotation of the knee joint, medially by about 9% ($P < .0001$) with internal rotation of the knee, and medially by about 3% ($P = .0001$) with ESQ. During external rotation of the knee joint, ESQ induced medial displacement of PPCR by about 2% ($P = .041$), whereas ESQ induced lateral displacement of PPCR by about 4% ($P < .0001$) during internal rotation of the knee.

In group 2 the mean PsI value of female patients was significantly smaller than that of male patients by 21.3% ($P = .019$). No other significant differences were noted in the other measurement results between the sexes. PoN was about 57%, indicating that PPCR was located more laterally to the middle of the lateral facet of the trochlear groove. PPCR was shifted laterally by about 29% ($P < .0001$) with external rotation of the knee joint, medially by about 33% ($P < .0001$) with internal rotation of the knee, and medially by about 1% ($P = .55$) with ESQ. During external rotation of the knee, ESQ induced lateral displacement of PPCR by about 18% ($P < .0001$), resulting in the most lateral PPCR in this study, whereas ESQ induced medial displacement of PPCR by about 7% ($P = .008$) during internal rotation of the knee.

The mean values of all 6 PPCR measurements in group 2 were significantly higher than those in group 1. Significant differences were also seen between the 2 groups in the effects of rotation of the knee joint on PPCR and those of ESQ during rotation of the knee joint. The mean directions of the patellar shift of the 2 groups were the same in the effects of rotation of the knee joint but opposite in the effects of ESQ during rotation of the knee joint.

The AUCs of each measurement and effect are shown in Table 2. Arthroscopic measurement of PPCR with external rotation of the knee plus ESQ was the only method that showed an AUC of 1 (sensitivity, 100%;

### Table 2. Results of Radiographic and Arthroscopic Measurements of Patellofemoral Congruence of Each Group and AUC

<table>
<thead>
<tr>
<th>Measure</th>
<th>Group 1</th>
<th>Group 2</th>
<th>AUC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congruence angle (°)*</td>
<td>4.7 ± 10.3</td>
<td>27.2 ± 24.6</td>
<td>0.854</td>
</tr>
<tr>
<td>Patella position (Po) (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PoN*</td>
<td>4.7 ± 6.2</td>
<td>57.2 ± 27.5</td>
<td>0.963</td>
</tr>
<tr>
<td>PoE*</td>
<td>13.6 ± 15.0</td>
<td>86.2 ± 17.7</td>
<td>0.994</td>
</tr>
<tr>
<td>PoI*</td>
<td>9.5 ± 12.6</td>
<td>89.4 ± 18.5</td>
<td>0.885</td>
</tr>
<tr>
<td>Patella position during ESQ (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESR (Ps) (%)</td>
<td>1.4 ± 3.3</td>
<td>58.5 ± 29.9</td>
<td>0.948</td>
</tr>
<tr>
<td>PoN</td>
<td>0.8 ± 2.5</td>
<td>61.8 ± 34.5</td>
<td></td>
</tr>
<tr>
<td>PoI</td>
<td>1.9 ± 3.7</td>
<td>56.6 ± 27.9</td>
<td></td>
</tr>
<tr>
<td>PoE</td>
<td>11.5 ± 14.6</td>
<td>103.8 ± 11.3</td>
<td>1.000</td>
</tr>
<tr>
<td>PoI</td>
<td>2.5 ± 13.0</td>
<td>105.5 ± 12.8</td>
<td></td>
</tr>
<tr>
<td>Patella position during ER (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESR (Ps) (%)</td>
<td>0.0 ± 0.3</td>
<td>17.3 ± 22.2</td>
<td>0.795</td>
</tr>
<tr>
<td>Effect of ER (PoE − PoN) (%)</td>
<td>8.9 ± 12.1</td>
<td>29.1 ± 21.1</td>
<td>0.840</td>
</tr>
<tr>
<td>Effect of ESQ during NR (PsN − PoN) (%)</td>
<td>3.3 ± 5.5</td>
<td>1.4 ± 11.4</td>
<td>0.737</td>
</tr>
<tr>
<td>Effect of ESQ during ER (PsE − PoE) (%)</td>
<td>2.1 ± 7.8</td>
<td>17.6 ± 11.6</td>
<td>0.986</td>
</tr>
<tr>
<td>Effect of ESQ during IR (PsI − PoI) (%)</td>
<td>4.0 ± 6.2</td>
<td>−5.7 ± 9.3</td>
<td>0.766</td>
</tr>
</tbody>
</table>

NOTE. Values are given as mean ± SD.  
ER, external rotation of knee; IR, internal rotation of knee; NR, neutral rotation of knee.

*Significant difference between groups 1 and 2 ($P < .0001$).  
1Significant difference between sexes ($P = .029$).  
2Significant difference between sexes ($P = .019$).  
3Significant difference between groups 1 and 2 ($P = .014$).
specificity, 100%), and the cutoff value of PoN was between 68.6 and 82.4.

The time required for arthroscopic examination of patellofemoral alignment was less than 10 minutes, and the amount of time of ESQ was less than 20 seconds. No complications related to arthroscopy through a proximal superomedial portal, rotational stress on knees, or ESQ occurred in any patients.

**Discussion**

The results of this study support our hypothesis. We observed significant differences in the effects of rotation of the knee joint and/or ESQ on patellofemoral congruence at 30° of flexion of the knee joint on arthroscopy between knees with and without patellar instability. External and internal rotation of the knee joint caused lateral and medial patellar shift, respectively, in both groups, but the shift was significantly larger in group 2. ESQ in addition to rotation of the knee joint caused further patellar shift in group 2 but reduced the patellar shift in group 1. Consequently, measurement of PPCR with external rotation of the knee and ESQ was the only method to show an AUC of 1. The correlation coefficient between the congruence angle and PoN was 0.82, which was lower than that between the congruence angle and the linear patellar displacement ($r > .9$) reported by Urch et al.\textsuperscript{20}. The reason for this difference may be that the latter is a comparison between 2 different measurements of patellofemoral alignment on the same radiograph whereas the former is a comparison between radiographic and arthroscopic measurements of the same knee joint.

PPCR of knee joints with neutral rotation was about 5% in group 1 and about 57% in group 2, showing a significant difference in the location of the patella between the 2 groups without rotational stress or ESQ. If PoN is used to diagnose patellar instability, the cutoff value of 22% shows a maximum accuracy of 96.4% (sensitivity, 95.7%; specificity, 96.7%). The AUC of PoN was 0.963, and that of the congruence angle was 0.854, which seems to indicate that general anesthesia and slightly increased intra-articular pressure provided a clearer differentiation between the 2 groups. When the knee joints were externally rotated, lateral displacement of PPCR was about 9% in group 1 and about 29% in group 2. On the other hand, when the knees were internally rotated, medial displacement was about 9% in group 1 and about 33% in group 2. These findings are in accordance with previous observations that the patella shifted medially or laterally with internal or external tibial rotation in the early phase of knee flexion\textsuperscript{21-23} but also that PPCR of knees with patellar dislocation was more likely to be displaced because of rotation of the knee joints. The reason the patella tracked further medially with internal rotation of the knee joint with a history of patellar dislocation is that PPCR was located near the center of the lateral facet of the trochlear groove before internal rotation was applied. Therefore the patella was easily reduced toward the deepest point of the trochlear groove with internal rotation of the knee joint. On the other hand, the patella could contact the medial facet of the trochlear groove with internal rotation of the knee joint without a history of patellar dislocation, which seems to disturb further medial displacement of the patella.

A significant difference was observed in the effect of ESQ with neutral rotation of the knee joint, showing that the patella shifted slightly medially in group 1 whereas the patella did not shift in group 2. The reason the patella with a history of dislocation did not shift with ESQ may be that the patella had already been located in a balanced position on the trochlear groove to the quadriceps force vector before ESQ. Significant differences were also observed between the 2 groups in the effect of ESQ with external and internal rotation of the knee joint, showing that the directions of the shifts of the patella caused by ESQ were opposite to each other. Consequently, the directions of the patellar shift caused by tibial rotation and by additional ESQ to the rotation were the same in group 2 but opposite in group 1. In other words, the direction of patellar displacement may depend on the original PPCR before ESQ. When PPCR is located around the deepest point of the trochlear groove, PPCR is likely to settle in the deepest point by ESQ, whereas when PPCR is located far lateral on the trochlear groove with external rotation of the knee, PPCR is likely to shift laterally with ESQ. Whether the patients showed a lateral patellar shift because of an abnormal quadriceps force vector or because of a lesser anatomically determined resistance to the lateral force caused by quadriceps action could not be investigated in this study. We were not able to measure the inclination angle of the lateral facet of the trochlear groove on a still frame of the patellofemoral joint because we could not draw a line parallel to the epicondylar axis or the line tangential to the posterior borders of the femoral condyle on the still frame. Strict positioning of the femur and a video camera during the examination might solve this problem.

Sex differences were observed in each group. In group 1 PPCR of female patients without knee rotation or ESQ was located significantly lateral to that of male patients. Because the mean values of the other 5 PPCR measurements in female patients were greater than or equal to those of male patients, the situation without knee rotation or ESQ might have clarified the sex difference in PPCR. In group 2 PPCR with internal rotation and ESQ was located significantly medial in female patients. The cause of this sex difference is unknown; however, a sex difference in the arc of
internal rotation of the knee joint or other sex-related factors including trochlear groove orientation may be involved.

This is the first investigation to show that abnormal patellar tracking can be seen with the described method. The equipment needed for stimulation of the quadriceps on arthroscopy is not special. Standard muscle stimulation devices that are usually used in physical therapy suffice. If this method can reproduce the most severe patellar maltracking, this method could be used to detect undiagnosed patellar malalignment or estimate the efficacy of the treatment during surgery by measuring how much the maltracking is corrected.

Limitations

Our study has several limitations. First, intra-articular pressure may have influenced the patellofemoral alignment pattern on arthroscopy, although the patella was reported to float up symmetrically with rising intra-articular pressure. We set the intra-articular pressure at 20 mm Hg to reduce the influence of fluid distension on the patellofemoral alignment as much as possible, although the adoption of 20 mm Hg may not be fully validated. Second, mounting a pneumatic tourniquet on the patient’s thigh may have influenced the muscle tone and the direction of the contraction force of the quadriceps, although the tourniquet was not inflated during arthroscopic examination of the patellofemoral joint. Third, the portal for arthroscopic examination may have interfered with patellar displacement. However, we used a superomedial portal for arthroscopic examination and an anteromedial portal for drainage of the irrigation solution so as not to interfere with lateral displacement of the patella induced by rotation of the knee joint or ESQ. Fourth, the anesthesia may have influenced the results of this study. A difference may exist in quadriceps muscle tonus in patients under general anesthesia without muscle relaxants compared with patients under spinal and/or epidural anesthesia. Because the former type of anesthesia is more likely to resemble the normal relaxed situation than the latter, we only included patients with general anesthesia in this study. Fifth, lens distortion of the arthroscopic image may have induced an error in the results of the patellofemoral alignment, although the distortion was digitally corrected by use of software. We took care not to select still frames in which the marginal 3% of the image was needed to measure the patellofemoral alignment because the marginal 3% of the original arthroscopic image was not sufficiently corrected. Sixth, the effect of the mode and amount of electrical stimulation on the resultant motion of the patella was not studied. However, the mode of electrical stimulation was reported to mostly affect the torque generated by muscle contraction. Moreover, ESQ does not seem to have induced apparent fatigue of the quadriceps during the examination because the biphasic waveform was used, the total amount of time required for ESQ was less than 20 seconds, and the contraction force generated by ESQ was less than that needed to elevate the crus against gravity. Seventh, there is a difference in the order of motor unit recruitment between voluntary contraction and electromyostimulation. In voluntary contraction, muscle fibers are recruited in an obvious sequence related to fiber type (i.e., type 1, 2a, and 2b), whereas in electromyostimulation, a nonselective and synchronous recruitment pattern of muscle fibers occurs, which may result in a difference in the location of the contraction in the quadriceps between these 2 types of contractions. However, the distribution of muscle fiber types is mosaic and differs only by muscle depth. Because we were able to see and palpate the contraction of all parts of the quadriceps muscle during ESQ in each patient, the difference in the direction of the contraction force between voluntary contraction and ESQ seems to be slight. Eighth, when the knee joints of the patients were rotated during arthroscopy, maximal manual force was applied. Therefore we do not know how much the knee joints were actually rotated or how much the knee joints were abducted or adducted accompanied by the rotational force, although varus and valgus stress is reported to have little effect on patellar position.

Conclusions

There were significant differences in the effects of rotation of the knee joint and/or ESQ on patellofemoral congruence at 30° of flexion of the knee joint on arthroscopy between knees with and without patellar instability.

References


