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Better Association Between Q Angle and Patellar Alignment Among Less Displaced Patellae in Females with Patellofemoral Pain Syndrome: A Correlation Study with Axial Computed Tomography

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1. Introduction

Q angle, as an isolated clinical tool, is of uncertain and limited clinical value. ¹ The Q angle, defined as the angle between the lines joining the anterior superior iliac spine, the center of the patella, and the center of the tibial tubercle, has been studied widely ^{2,3}. As a routine assessment tool in physical examination for clinical knee problems, with great inherent diversity in serving as a relevant clinical tool, the Q angle has long met debates in day to day orthopaedic practice. An increase in Q angle has long been looked as a pathologic factor in PFPS ^{4,5}. Presumably the larger the Q angle, the larger the lateral pulling force on the patella ², but reportedly Q angle rarely correlated with patellofemoral pain syndrome (PFPS) ^{6,7}. Livingston and Mandigo ⁷ reported that no correlations between the Q angle measures and the magnitude of discomfort experienced in unilateral knee pain sufferers; while these relationships were weak yet significant in bilateral knee pain sufferers.

Since last decade, computer tomography (CT) has become an important diagnostic tool for better assessment of patellofemoral disorders ^{8,9,10}. Biedert and Warnke ⁶ have carried out a correlation study between the Q angle and the patella position by axial CT evaluation in patients with PFPS, but failed to establish the diagnostic relevance of the Q angle in the related patellofemoral disorders ⁶. Other studies have revealed no significant correlation between Q angle and the position of patella in patients with PFPS. It has been stated that the

patella may be translated laterally in patients with patellofemoral malalignment and thereby artificially affect the measurement.¹ Reider has found a decrease in Q angle in chronic recurrent dislocation of patella, an increase in Q angle in the classic patellar pain pattern, often called "chondromalacia patella, and a normal mean Q angle in subluxated patellae.¹¹ Lin et al had a disclosure of a more apparent statistic trait via a deep exploration into the patellar alignment subtypes in a study of PFPS.¹² Given this; we speculated that patellar displacement exerts an effect on the Q angle to some extent. Since lateral displacement of the patella was found in most patients with PFPS, the Q-angle might be undervalued over the already laterally displaced patellae in patients with PFPS¹³. A deep exploration into the effect of lateral patellar displacement on Q angle measures might render a better disclosure of how the measure of Q angle and related clinical implication were affected by patellar displacement. The current study is thus aimed to execute a deeper prospective study of the correlation between Q angle and patellar alignments by treating the more displaced patellae and less displaced patellae separately to see whether Q angle might be varied with difference in patellar displacement. The hypothesis of this study was that the interaction dynamics between Q angle and patellar alignment may be varied with various status of patellar displacement.

Clinical Relevance: To endorse Q angle with a certain clinical value is important to clinical assessment of PFPS that prevails among females.

2. Materials and methods

2.1 Subjects

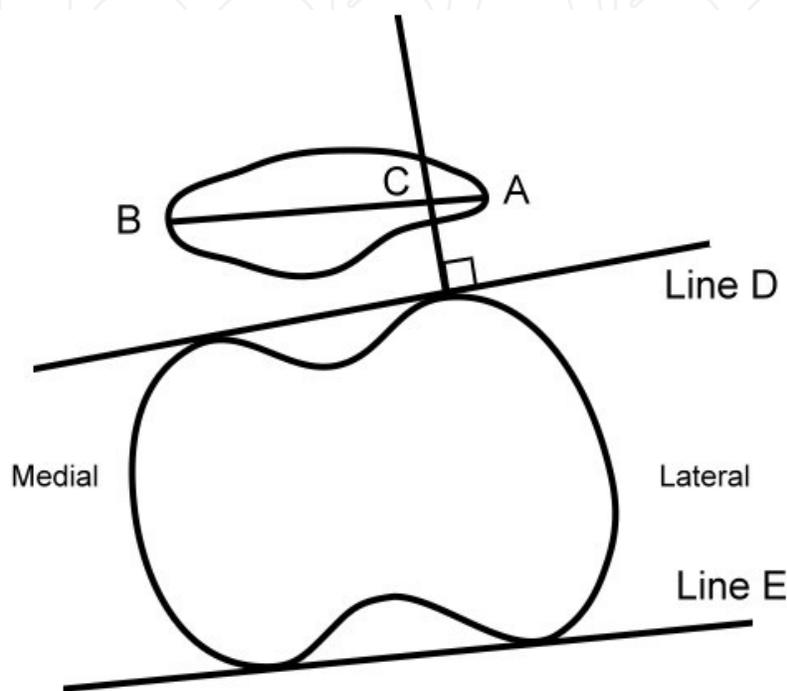
Among 50 female PFPS patients enrolled in the current study, there were 28 patients with PFPS over their both knees and 22 patients with PFPS unilaterally. All patients were examined with axial computed tomography for all knees. All PFPS knees came into the current study to explore the probable correlation between the Q angle and the patellar position. The inclusion criteria of PFPS were patients who were suffering from pain with more than three kinds of knee-flexing activities as sitting, getting up from sitting, walking upstairs or downstairs, squatting, getting up from squatting, running, kneeling, or jumping. The exclusion criteria included the presence of any major medical disease, rheumatoid arthritis, or gouty arthritis; past history of previous knee surgery, image findings of osteoarthritis, or any deformity of lower limbs. All were measured for body weight, body height, BMI, and Q angle. The Q angle was measured, with the patient lying supine, as the angle between the lines joining the anterior superior iliac spine, the center of the patella, and the tibia tubercle^{2,3}. The same goniometer was used for every patient and the same senior doctor taking all of the measurements. All patients underwent CT imaging of the knees in the same way as Gigante's methods⁹.

2.2 CT imaging

Computed tomography was performed with a Pace General Electric machine (GE Medical Systems). The patient was in the supine position and the scans were obtained in knee extension with the quadriceps relaxed. The ankles were restrained with felt strips to prevent external rotation of the foot. An axial image was obtained through the widest diameter of the patella, which allows the best view of the patellofemoral joint for the related measurement of patellar alignment⁹.

2.3 CT measurements of patellar displacement

Lateral patella shift of Sasaki (LS)¹⁴, used to represent patellar positions, is the ratio of the lateral portion of transverse patellar line relative to the medial one (AC / BC). "C" is the point on the transverse patellar line (AB) intersected by a line that is drawn from the most convex point of the lateral femoral condyle and perpendicular to the line (Line D) along the anterior border of femoral condyles.. (Figure 1) The interrelation between the Q angles and CT measurements were investigated.



$$\text{Lateral Shift of Sasaki (LS): } AC/BC * 100\%$$

Fig. 1. Measurement made from CT images for lateral patella shift of Sasaki (LS). "LS" is the ratio of the lateral portion of transverse patellar line relative to the medial one (AC / BC). "C" is the point on the transverse patellar line (AB) intersected by a line that is drawn from the most convex point of the lateral femoral condyle and perpendicular to the line (Line D) along the anterior border of femoral condyles.

2.4 Statistical analysis

SPSS (version 11.5, SPSS Inc, Chicago, IL) statistical soft ware was used to execute all statistical analyses. The statistic tool used includes t test for the difference in measurement between study groups. The Pearson's correlation was used to investigate the relation between the Q angle and the measurement for patellar displacement, LS. For all statistical tests, the significance level was set at $p < .05$. To further examine the relationship between the Q angle and the measurements for patellar positions, the whole sample was grouped as: group 1 that was divided into those knees whose mean LS were below 20 percentiles of the whole sample and those knees whose mean were over 20 percentiles, group 2 that was divided into those knees whose mean LS were below 30 percentiles of the whole sample and those knees whose mean were over 30 percentiles, and group 3 that was divided into those

knees whose mean LS were below 40 percentiles of the whole sample and those knees whose mean were over 40 percentiles. And a test with ROC curve was done for the specificity and sensitivity of the presence of patellar pain relative to Q angle. The area under the ROC curve was used to anticipate the pathognomonic potential of the Q angle. (Figure 2)

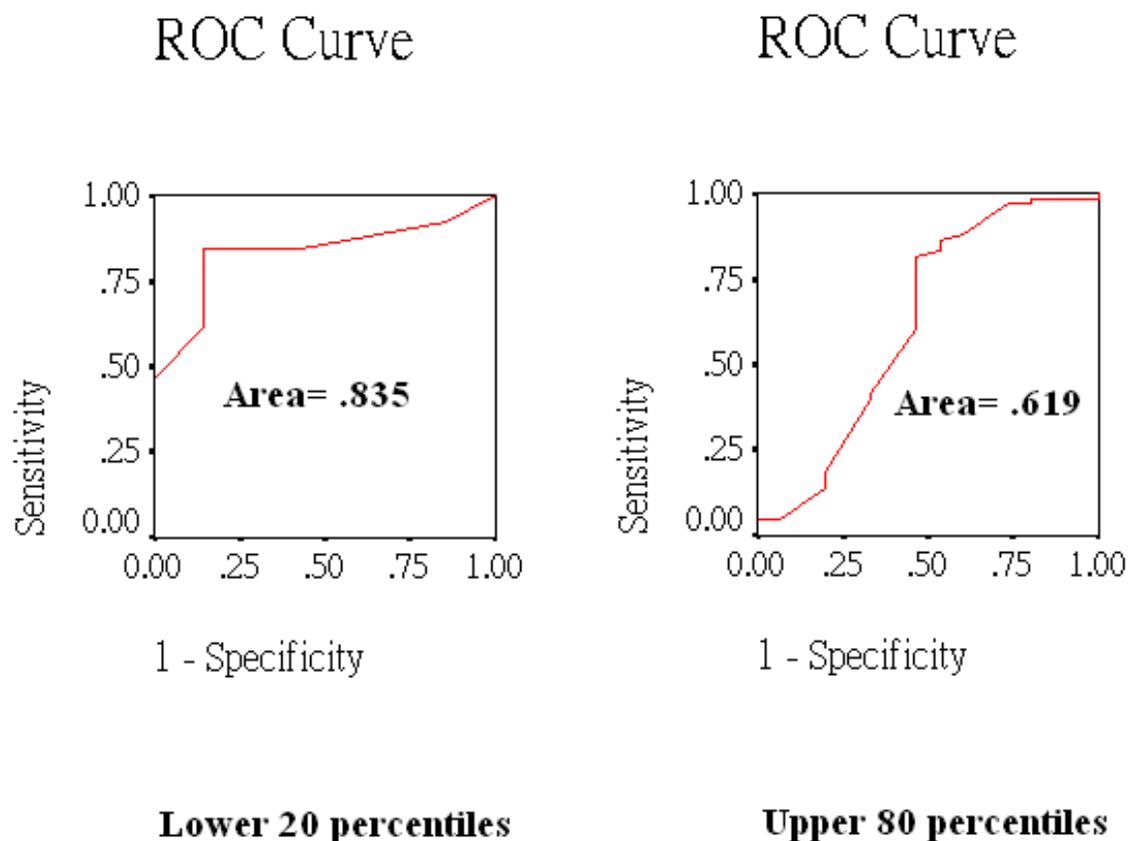


Fig. 2. Test with ROC curve for the specificity and sensitivity of the presence of patellar pain relative to Q angle.

3. Results

Q angle was significantly correlated to the measure of patellar displacement, LS, in the less displaced half of LS measures of each group. And an area of .730 to .835 was revealed by the test with ROC curve in the subgroups of less displaced patellae.

In total, the subjects aged 40.14 ± 9.99 years, and their the basic demographics was: body weight, 57.18 ± 8.55 kg, body height, 158.48 ± 5.48 cm, and BMI, 22.75 ± 3.09 . The Q angle was 23.98 ± 7.61 degrees, and LS, 35.99 ± 14.03 in %. The Q angle and LS measures in each group and subgroup were shown in Table 1. There was no significant difference in Q angle between the subgroups in each group. ($p < 0.05$) (Table 1)

Statistic correlation was undertaken to explore the probable correlation between Q angle and patellar position, measured in LS. There was no correlation between Q angle and LS when the whole sample of 100 knees was calculated as a whole. After analysis into subgroups of different cutoff, a significant correlation was disclosed between Q angle and LS in the subgroup of knees with less displaced patellae in each group of respective way of cutoff. ($p < 0.05$) (Table 2)

	Group 1 Cutoff 20%: 24.00mm		Group 2 Cutoff 30%: 27.87mm		Group 3 Cutoff 40%: 32.16mm	
	Lower 20 percentiles (n= 20)	Upper 80 percentiles (n= 80)	Lower 30 percentiles (n= 30)	Upper 70 percentiles (n= 70)	Lower 40 percentiles (n= 40)	Upper 60 percentiles (n= 60)
Q angle (deg)	21.45±6.08	24.61±7.85	23.37±7.09	24.24±7.86	24.35±7.83	23.72±7.52
LS (%)	18.60±4.28**	40.33±12.10	21.11±5.06**	42.36±11.58	23.34±5.90**	44.42±11.24

There was significant difference in LS between any two subgroups within any group ($p < 0.01$). There was no significant difference in Q angle between the subgroups within any group. ($p < 0.05$)

Table 1. Measurements of Q angles and patellar position (LS) in study groups

Via the test with ROC curve for the specificity and sensitivity of the presence of patellar pain relative to Q angle, an area of .730 to .835 was revealed in the less displaced half of LS measures of each group, indicating that Q angle would be more pathognomonic of PFPS among patients or knees of less displaced patellae. (Figure 2, Table 2)

	Group 1 Cutoff 20%: 24.00mm		Group 2 Cutoff 30%: 27.87mm		Group 3 Cutoff 40%: 32.16mm	
	Lower 20 percentiles (n= 20)	Upper 80 percentiles (n= 80)	Lower 30 percentiles (n= 30)	Upper 70 percentiles (n= 70)	Lower 40 percentiles (n= 40)	Upper 60 percentiles (n= 60)
Correlation coefficient ^a	0.481*	-0.175	0.502**	-0.142	0.453**	-0.096
Area under ROC curve ^b	0.835	0.619	0.780	0.634	0.730	0.657

^a: Correlation coefficient between Q angle and lateral shift of patella (LS)
^b: Diagnostic tests: probability of correctly distinguishing between painful and non-painful knees
 *: $p < 0.05$; **: $p < 0.01$

Table 2. Correlation coefficient between Q angle and lateral shift of patella (LS). And diagnostic tests between subjects with and without painful knees.

4. Discussion

We have hypothesized that the interaction dynamics between Q angle and patellar alignment may be varied with various status of patellar displacement. After deep exploration into the subgroups of LS, the current study has demonstrated that Q angle was significantly correlated to the measure of patellar alignment, LS, in the less displaced half of LS measures of each group of respective cutoff point for LS. And via the test with ROC curve for the specificity and sensitivity of the presence of patellar pain relative to Q angle, an area of .730 to .835 was observed to be under the ROC curve in the less displaced half of LS measures of each group, indicating that Q angle would be more pathognomonic of PFPS among patients or knees of less displaced patellae.

Reportedly, a decrease in Q angle has been observed in chronic recurrent dislocation of patella, an increase in Q angle in the classic patellar pain pattern, often called

"chondromalacia patella, and a normal mean Q angle in subluxated patellae.¹¹ While, Biedert and Warnke's reported failure to conclude any correlation between the Q angle and the patellar displacement in their experiment⁶. Quite similar to Biedert and Warnke's work⁶. Our current study also showed no correlation between the Q angle and the patellar displacement when analyzing all the subject knees of PFPS as a whole. When the more displaced patellae and the less displaced half were evaluated separately, a significant correlation was observed between the Q angle and the patellar displacement among those with less displaced patellae in our study.

The concept of the "larger the Q angle, the larger the lateral pulling force on the patella" has been challenged, one after another, in the literature. Dandy has reported that an unstable, subluxated patella lies more laterally than normal, thereby decreasing the Q angle¹⁵. By statistically treating the more displaced patellae and the less displaced ones separately in the 3 ways of cutting off for the LS measures, the current study has revealed a positive correlation between Q angle and patellar displacement among those with less displaced patellae. The Q angle has been presumed to be responsible for the bowstring effect³, whereby the patella tends to move laterally as the quadriceps contracts. Actually it is the underlying valgus vector force of the Q angle, rather than the Q angle per se, that dominates the way that the instantaneous bowstring assumes. As thus the Q angle and the instantaneous center of the patella landmarks the way the instantaneous bowstring assumes. Apparently Q angle failed to mean a comparable degree of the valgus vector across the knee of PFPS. As revealed in the current study, Q angle was equivocally obscured by patellar displacement that was the presumed result of the valgus across the knee. As thus the degree of valgus across the knee could be better represented by Q angle together with patellar displacement. In the current study there was no significant difference in Q angle between the subgroups in each group. We failed to observe Q angle as being undervalued by patellar displacement even if a consistent trait of negative association between Q angle and patellar displacement (LS) has been demonstrated in each subgroup of more displaced patellae in each group. (Table 2) We failed to verify Post's concept that the patella may be translated laterally in patients with severe patellofemoral malalignment and thereby artificially decrease the measurement of the Q angle^{1, 2}.

The natural valgus of the lower limb and the lateral pulling vector of the quadriceps migrates the patella laterally.^{15, 16} An abnormal or increased Q angle is considered a relevant pathologic factor in patellofemoral disorder⁶. When the Q angle exceeds 15-20° it is thought to contribute to knee extensor mechanism dysfunction by increasing the tendency for lateral patella malpositioning¹⁷. Previous investigations of the quadriceps angle (or Q angle) and its relationship to knee disorders have yielded equivocal results.^{6, 9, 10, 18} Reportedly Q angle failed to dictate the PFPS symptom and the presumed patellar malalignment leading to PFPS. Previous studies from various investigators have failed to correlate Q angle measurements with patient complaints. Fairbank et al have demonstrated no significant difference between painful and pain free knees¹⁹. There is no specific correlation between patellar symptomatology and an increased Q angle, as thus the clinical value of measuring the Q angle has been much controversial²⁰. In the current study, via the test with ROC curve for the specificity and sensitivity of the presence of patellar pain relative to Q angle, an area of .730 to .835 was observed under the ROC curve in the less displaced half of LS measures of each group of respective cutoff point, indicating that Q angle would be more pathognomonic of PFPS among patients or knees of less displaced patellae. Likewise, the

current study has endorsed Q angle with a certain clinical value among people who are with less displaced patellae. The result will be important to clinical assessment of PFPS that prevails among females and athletes²⁰.

For the time being, the diagnostic relevance of the Q angle is highly equivocal. The Q angle has been subjected to a radical modification in order to play a positive clinical tool and provide a certain clinical value. Fithian et al has proposed a modified Q angle by measuring it in 30° of knee flexion with the patella manually reduced into the trochlea²¹. By analyzing all subject knees into different subtypes of patellar displacement to reveal an association between Q angle and patellar alignment and to endorse the Q angle with a promising pathognomonic value among PFPS patients or knees of less displaced patellae, the current study would help motivate further revision and endorsement of the Q angle in regard.

Reportedly a significant difference in Q angle between sides has led to a statement that symmetry in right versus left lower limb Q angle measures may be erroneous. And this is why both knees of PFPS patients with bilateral knee pain were enrolled into the current study instead of one person one knee^{7, 22}. Additionally, in our series, there was a significant difference in Q angle between sexes in our unopened observations ($p < 0.01$) This is why the male were excluded from the current study. As thus the current design merely focused on female population. Women have been stated to have higher Q angles than men, on the basis of a wider pelvis^{23, 24}. Some has reported minimal difference in the Q angle measure between men and women³; while some has reported higher Q angle in men^{19, 25}.

The limitation of this study is failure to execute the interaction dynamics between Q angle and patellar position under weight bearing condition. A further study with open MR would make possible the related study under weight bearing condition.

In conclusion, Q angle was significantly correlated to patellar alignment among people with less displaced patellae. Q angle was more pathognomonic of patellar pain in those people with less displaced patellae.

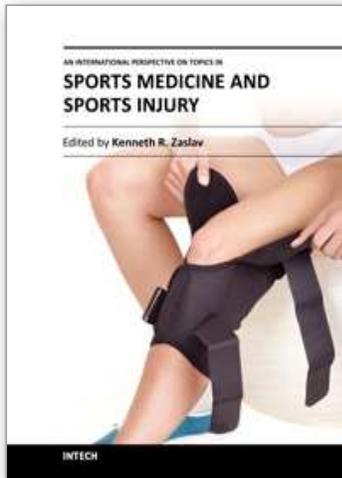
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