A Study on the Optimal Angle as Modified Tangential Projection of Knee Bones

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Received: October 01, 2021. Revised: November 26, 2021. Accepted: November 30, 2021

ABSTRACT

In this study, we wanted to find out the optimal angle as a modified tangential projection of the patella. In the experiment, we used Kyoto Kagaku's PBU-50 phantom. In the supine position, the F-T angle was set to 95°, 105°, 115°, 125°, 135°, 145°, and Patella tangential projection images were obtained by varying the X-ray tube angle by 5° so that the angle between the X-ray centerline and tibia at each angle was 5~20°. Image J was used for image analysis and the congruence angle, lateral patellofemoral angle, patellofemoral index and contrast to noise ratio(CNR) were also measured. SPSS 22 was used for statistical analysis, and the mean values of congruence angle, patellofemoral angle, patellofemoral index, and CNR were compared with Merchant method through one-way batch analysis and corresponding sample t-test. As a result of the study, in the case of congruence angle, the angle of incidence of the knee-angle X-ray centerline was 105°-72.5° (20° tangential irradiation), 115°-72.5°, 77.5° (15, 20° tangential irradiation), 125°-82.5° (20° tangential irradiation), lateral patellofemoral angle is 115°-72.5°, 77.5° (15, 20° tangential irradiation), 125°-72.5° (10° tangential irradiation), patellofemoral index is 115°-72.5° (15° tangential irradiation) and 125°-72.5° (10° tangential irradiation) were not significantly different from Merchant method (p> .05). In case of CNR, it is not different from Merchant method at 105°-67.5°, 72.5° (15, 20° tangential irradiation), 115°-67.5°, 72.5°, 77.5° (10, 15, 20° tangential irradiation). (P> .05). Based on the results of this study, high diagnostic value images can be obtained by setting the knee angle and the angle of incidence of the X-ray tube to 115°-72.5° (15° tangential irradiation) during the modified tangential examination of the knee bone. It was confirmed.

Keywords: Patella, Merchant, tangential view, Congruence angle, Lateral patellofemoral angle, Patellofemoral index

I. INTRODUCTION

The knee X-ray examination is performed to identify the overall condition such as alignment of the knee joint, joint spacing, and changes in bone tissue, and is known as the most basic and important radiology examination in terms of cost and time. Among them, the tangential test is easier to observe the relationship between the knee and the femur than the anterior-posterior and lateral tests, so it is essential when a diagnosis of knee subluxation or loss of joint spacing is required[1-3]. In order to evaluate the knee subluxation and joint loss, it is basically necessary to measure the sulcus angle, so it is the most important to acquire a tangential image that clearly depicts the trochlear sulcus[1,2,10]. Generally, when the F-T angle (femur-tibia angle) decreases by bending the knee during the knee tangential examination, the knee appears adjacent to the trochlear sulcus, which is likely to be diagnosed as false negative of

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subluxation[4-6,11]. If you stretch your knee, and the F-T angle is increased, there is a limitation in that it is difficult to irradiate the central X-ray in the tangential direction to the knee joint[7,8,12]. Thus, various studies have been conducted to obtain the optimal image tangential to the knee. In the current clinical trial, the method of irradiating the central X-ray at 60° toward the leg at an F-T angle of 45° devised by Merchant et al[2,4,9]. is mainly used in terms of image distortion and dose reduction. However, the method has a limitation in that it is difficult to apply to patients who cannot bend their knees due to pain or those who have difficulty moving in bed because it is necessary to use an auxiliary device that makes the F-T angle 45° and the patient's cooperation for positioning. In this study, therefore, we attempted to find out the modified tangential direction test that can reduce image distortion through various F-T angles and changes in the incident angle of the central X-ray. Based on the above, we are to suggest a method that can minimize the knee bending and movement of the patient while maintaining the diagnostic value such as the knee tangential examination currently used in clinical practice.

II. MATERIAL AND METHODS

1. Experimental Equipment

In this experiment, GE's Definium 8000 DR system and Kyoto Kagaku's PBU-50 phantom were used.

2. Experimental Method

In the supine position, a fixture is used to bend the FT angle (femur tibia angle) to 95°, 105°, 115°, 125°, 135°, 145°, and take pictures by changing the tube angle by 5° (62.5°, 67.5°, 72.5°, 77.5°, 82.5°, 87°, 87.5°) in each so that it becomes 5~20°. As shown in Fig. 1, the irradiation direction of the center line was caudal, and SID 100 cm, FOV 15×10 cm images in the tangential direction of the knee were acquired 10 times.

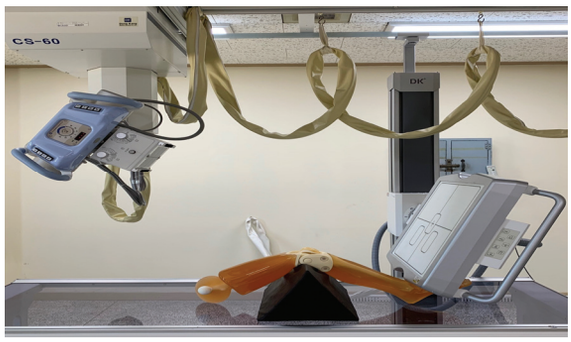

Fig. 1. Modified Tangential View.

3. Image Evaluation Items

For image evaluation, 4 items were measured in each image. If the F-T angle increased by 145° or more when measuring the above items, tangential irradiation was not possible, which was excluded from the study. The four items are as follows:

3.1 Congruence Angle

As shown in Fig. 2, the angle formed by the line connecting the intercondylar sulcus at the lowest vertex of the knee joint eminence and the line dividing the sulcus angle (the angle formed by two lines connecting the deep part of the femoral groove and the high part of both femoral condyles) is called the Congruence angle[4,5].

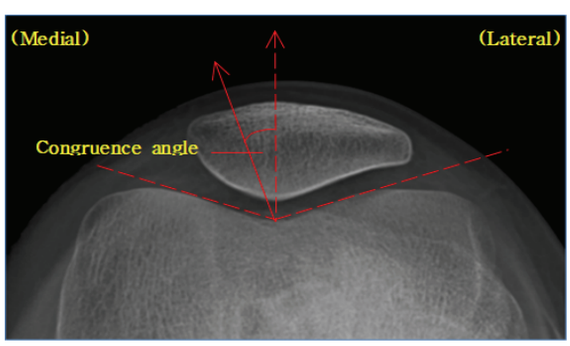

Fig. 2. Congruence Angle.

3.2 Lateral Patellofemoral Angle

As shown in Fig. 3, the angle between the line connecting the front of the femur medial condyle, the lateral condyle and the vertical line connecting the

front of the knee is called the lateral patellofemoral angle[4].

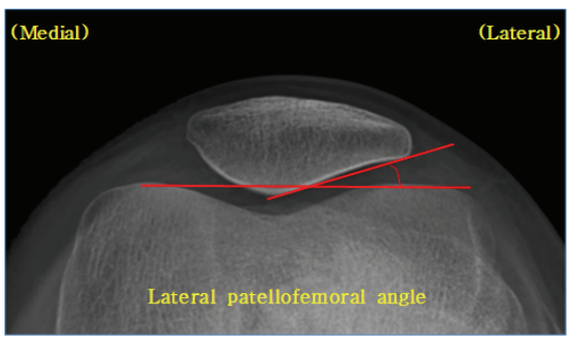

Fig. 3. Lateral Patellofemoral Angle.

3.3 Patellofemoral Index

As shown in Fig. 4, it refers to the ratio of the minimum distance between the articular ridge and the femur medial condyle to the minimum distance between the lateral femur condyle and the lateral articular surface of the knee, and 1.6 or less is normal[6].

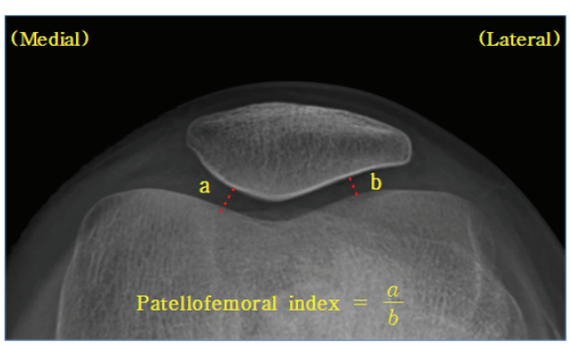

Fig. 4. Patellofemoral Index.

3.4 CNR(contrast to noise ratio)

NR is a measured value used to determine image quality. Being similar to the metric system, signal to noise ratio (SNR), it is the value obtained by subtracting the term before taking the ratio as in Eq. (1)[7].

$$CNR = \frac{|PV_V - PV_B|}{\sqrt{\frac{\sigma\frac{2}{V} + \sigma\frac{2}{B}}{2}}} \quad (1)$$

4. Statistical Analysis

After measuring the above four items, we used SPSS (V. 22. Chicago, IL, USA) for the statistical analysis. Through one-way ANOVA and Duncan's post-hoc analysis, the mean values of congruence angle, lateral patellofemoral angle, and patellofemoral index according to changes in the F-T angle and incident angle of central X-ray were compared with those of the Merchant method. In addition, a paired-sample t-test was performed to identify the difference in the mean CNR of each image according to the change in the F-T angle and the incident angle of central X-ray. All statistical results were judged to have a significant difference when the p-value was less than 0.05.

III. RESULT

According to the result of the normality test of congruence angle, lateral patellofemoral angle, patellofemoral index, and CNR (contrast to noise ratio) using the Shapiro-Wilk test, all items were found to be p>.05, satisfying normality.

1. F-T Angle (femur tibia angle) and Congruence Angle according to Tube Angle Change

Table 1 shows the results of the congruence angle depending on changes in the F-T angle and tube angle. When the F-T angle was 105° and the tube angle was 72.5° (20° tangential irradiation), there was no significant difference from the Merchant method (p>.05) (Table. 1). Also, when the F-T angle was 115° and the tube angles were 72.5° and 77.5° (15°, 20° tangential irradiation), there was no significant difference from the Merchant method (p>.05) (Table 1). When the F-T angle was 125° and the tube angle was 82.5° (20° tangential irradiation), there was no difference from the Merchant method (p>.05) (Table 1).

Table 1. Mean Congruence Angle according to Method

Method (F-T angle-Tube angle)	Congruence angle	*p	**Post-hoc
Merchant (a)	14.98±1.00		
95°-62.5° (b)	17.05±0.53		
95°-67.5° (c)	19.22±0.58	.000	a<b<c<d
95°-72.5° (d)	21.26±0.79		
105°-62.5° (e)	17.08±0.98		
105°-67.5° (f)	16.73±0.85	.000	g,a<e,f
105°-72.5° (g)	14.62±0.66		
115°-67.5° (h)	16.65±1.42		
115°-72.5° (i)	15.02±0.81	.002	a,i,j<h
115°-77.5° (j)	15.37±0.84		
125°-72.5° (k)	17.47±0.80		
125°-77.5° (l)	16.09±0.88	.000	a<l<k
125°-82.5° (m)	15.48±1.16		
135°-77.5° (n)	35.87±1.30		
135°-82.5° (o)	28.48±1.19	.000	a<p<o<n
135°-87.5° (p)	26.46±0.78		
145°-82.5° (q)	35.98±1.17	.000	a<q,r
145°-87.0° (r)	36.45±0.91		

2. Lateral Patellofemoral Angle according to changes in the F-T Angle and Tube Angle

Table 2 shows the results of lateral patellofemoral angle depending on changes in the F-T angle and tube angle. When the F-T angle was 115° and the tube angles were 72.5° and 77.5° (15°, 20° tangential irradiation), there was no difference from the Merchant method (p>.05) (Table 2). When the F-T angle was 125° and the tube angle was 72.5° (10° tangential irradiation), there was no significant difference from the Merchant method (p>.05) (Table 2).

3. Patellofemoral Index according to changes in the F-T Angle and Tube Angle

Table 3 shows the results of the patellofemoral index according to changes in the F-T angle and the tube angle. When the F-T angle was 115° and the tube angle was 72.5° (15° tangential irradiation), there was no significant difference from the Merchant method (p>.05) (Table 3). Also, when the F-T angle was 125°, there was no significant difference from the Merchant method even at a tube angle of 72.5° (10° tangential irradiation) (p>.05) (Table 3).

Table 2. Mean Lateral Patellofemoral Angle according to Method

Method (F-T angle-Tube angle)	Congruence angle	*p	**Post-hoc
Merchant (a)	14.07±0.68		
95°-62.5° (b)	9.94±0.60		
95°-67.5° (c)	10.86±0.68	.000	b<c<d<a
95°-72.5° (d)	12.30±0.70		
105°-62.5° (e)	11.79±1.02		
105°-67.5° (f)	13.14±1.03	.000	e<g,f<a
105°-72.5° (g)	12.96±0.80		
115°-67.5° (h)	13.13±0.82		
115°-72.5° (i)	13.68±0.51	.006	h<a
115°-77.5° (j)	13.78±1.04		
125°-72.5° (k)	13.89±0.77		
125°-77.5° (l)	15.71±0.93	.000	k,a<l,m
125°-82.5° (m)	16.04±0.96		
135°-77.5° (n)	15.84±1.01		
135°-82.5° (o)	16.75±0.84	.000	a<n<o,p
135°-87.5° (p)	17.07±0.77		
145°-82.5° (q)	17.37±0.50	.000	a<q<r
145°-87.0° (r)	18.12±0.69		

Table 3. Mean Patellofemoral Index according to Method.

Method (F-T angle-Tube angle)	patellofemoral index	*p	**Post-hoc
Merchant (a)	0.45±0.03		
95°-62.5° (b)	0.37±0.04		
95°-67.5° (c)	0.36±0.03	.000	c,b,d<a
95°-72.5° (d)	0.38±0.03		
105°-62.5° (e)	0.39±0.02		
105°-67.5° (f)	0.40±0.02	.000	e<g<a
105°-72.5° (g)	0.41±0.03		
115°-67.5° (h)	0.43±0.02		
115°-72.5° (i)	0.45±0.02	.000	h<i,a<j
115°-77.5° (j)	0.47±0.01		
125°-72.5° (k)	0.46±0.01		
125°-77.5° (l)	0.49±0.02	.000	a,k<l,m
125°-82.5° (m)	0.50±0.02		
135°-77.5° (n)	0.51±0.02		
135°-82.5° (o)	0.52±0.02	.000	a<n,o,p
135°-87.5° (p)	0.52±0.02		
145°-82.5° (q)	0.62±0.02	.000	a<q<r
145°-87.0° (r)	0.67±0.01		

4. CNR according to change in the F-T Angle and Tube Angle

Table 4 shows the results of CNR according to changes in the F-T angle and tube angle. When the F-T angle was 105° and the tube angles were 67.5° and 72.5° (15°, 20° tangential irradiation), there was no difference from the Merchant method (p>.05) (Table 4). In addition, when the F-T angle was 115° and the tube angles were 67.5°, 72.5° and 77.5° (10°, 15°, 20° tangential irradiation), there was no significant difference from the Merchant method (p>.05) (Table 4). When the F-T angle was 125° and the tube angle was 72.5° (10° tangential irradiation), there was also no difference from the Merchant method (p>.05) (Table 4).

Table 4. The Values are supplied by CNR Measurement according to F-T Angle and Tube Angle

F-T angle	Tube angle	mean±SD	*p
Merchant(ref)		63.36±1.87	0.00
95	625	49.36±0.78	0.00
95	675	57.57±2.23	0.00
95	725	57.86±3.91	0.00
105	625	58.35±3.22	0.00
105	675	61.15±3.30	0.93
105	725	62.62±2.46	0.06
115	675	62.67±3.99	0.59
115	725	62.62±2.46	0.32
115	775	62.17±2.99	0.09
125	725	61.10±3.30	0.05
125	775	60.64±3.47	0.03
125	825	33.15±2.60	0.00
135	775	25.95±2.15	0.00
135	825	17.10±2.46	0.00
135	875	21.10±2.65	0.00
145	825	15.83±1.67	0.00
145	870	16.16±1.71	0.00

IV. DISCUSSION

This experiment was conducted to prepare a test method that can minimize the change in the patient's posture and obtain an optimal image during the knee tangential examination. Existing knee tangential examination methods include Settegast view, Hughston view, Laurin view, and Merchant view[8]. Among them, the Settegast view and Hughston view bend 90° and 60°, so the knee may be subdued and produce false negatives[2]. In addition, since the patient's knee joint is extended in a prone position, it is difficult to accurately determine whether the knee is dislocated or not due to the load on the knee[9]. Therefore, the Settegast view and Hughston view were not suitable as a standard for comparison with the test method to be obtained in this experiment. The Laurin view is a test method in which the patient directs his/her knee toward the ceiling in a lying or sitting position, flexes his/her knee joint by 20°, and then irradiates the detector vertically with radiation[10]. Although the Laurin view is accurate for finding lesions of the knee-thigh joint[11], this test method was also not suitable as a standard for the test method to be obtained in this experiment because the patient is exposed to a lot of radiation dose. The Merchant view is a test method in which the knee joint is constantly bent at 45° using an auxiliary device and radiation is irradiated from the vertical plane to the foot at 60°. The Merchant view is used the most because it is more accurate than other test methods and patients are exposed to less radiation dose[2]. The merchant method is the most frequently performed test to measure the dissonance of the articular surfaces between the patella and the femur. However, since it is a difficult inspection method without auxiliary equipment, a weight-bearing axial view inspection performed in a standing position was developed for the purpose of improving work efficiency. According to previous research, Considering that the difference between the angle between the horizontal plane of the thigh and the prominence of the epicondyle is 2.9 degrees in the merchant examination after total knee arthroplasty, the 56-57 degree projection is easier to observe than the existing 60 degree angle. Therefore, the Merchant view was most suitable as the standard

of the test method to be obtained in this experiment. In order to obtain an image similar to the merchant view, the F-T angle and the tube angle were compared after shot at various angles. Unfortunately, however, there was no significant difference by angle because the experiment was conducted using a phantom. Since this experiment was not conducted directly on patients, it has a limitation that there is a possibility of correction and supplementation of the experimental results when actually applied to patients. In clinical practice, it is impossible to measure the angle of a patient's legs in a short time. Therefore, it is judged that an examination may be more accurate when the examination is applied through the manufacture of an auxiliary device that can fix the leg angle at a certain angle, which is found to be the most appropriate in a future paper. This paper was aimed at Phantom. Therefore, various variables such as age, gender, and medical history cannot be considered, so we plan to conduct research on human subjects in the future to improve the degree of completeness.

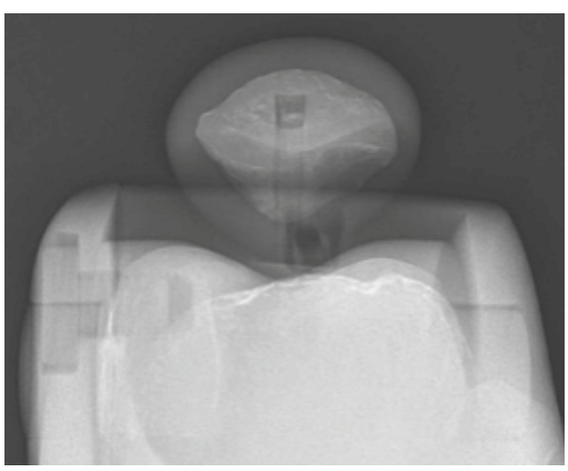

Fig. 5. Modified tangential image.

V. CONCLUSION

Modified tangential direction shooting was devised for patients who cannot take the Merchant method position. The result of experimenting with various angles showed that the shown in Fig. 5 image most similar to the Merchant method and high in diagnostic value could be obtained when the F-T angle and the tube angle were set to 115°-72.5° (15° tangential irradiation), respectively.

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무릎뼈의 변형된 접선방향 검사 시 최적의 입사각에 관한 연구

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요 약

본 연구는 무릎뼈의 변형된 접선 방향 검사 시 최적의 입사각에 대해 알아보고자 하였다. 실험은 Kyoto Kagaku사의 PBU-50 phantom을 이용하여 바로 누운 자세에서 넙다리뼈-정강뼈 각도(Femur-tibia angle, F-T angle)를 95°, 105°, 115°, 125°, 135°, 145°로 각각에서 X선 중심선과 정강뼈가 이루는 각도가 5~20° 되도록 5°씩 변경하여(62.5°, 67.5°, 72.5°, 77.5°, 82.5°, 87°, 87.5°) 무릎뼈 접선 방향 영상을 획득하였다. 영상분석을 위해 Image J를 이용하여 Congruence angle, Lateral patellofemoral angle, Patellofemoral index, 대조도 잡음비(Contrast to noise ratio, CNR)를 측정하였다. 통계 분석은 SPSS 22를 이용하여 일원배치분산분석과 대응표본 t-검정으로 Merchant method와 비교하였다. 연구 결과 Congruence angle의 경우 무릎 각도-X선 중심선의 입사각도가 105°-72.5°(20° 접선조사), 115°-72.5°, 77.5°(15, 20° 접선조사), 125°-82.5°(20° 접선조사), Lateral patellofemoral angle은 115°-72.5°, 77.5°(15, 20° 접선조사), 125°-72.5°(10° 접선조사), Patellofemoral index는 115°-72.5°(15° 접선조사), 125°-72.5°(10° 접선조사)에서 Merchant method와 유의한 차이가 없었다(p>.05). CNR의 경우 105°-67.5°, 72.5°(15, 20° 접선조사), 115°-67.5°, 72.5°, 77.5°(10, 15, 20°접선 조사)일 때 Merchant method와 차이가 없는 것으로 나타났다(p>.05). 본 연구의 결과를 통해 무릎뼈의 변형된 접선방향 검사 시 무릎 각도와 X선관의 입사각도를 각각 115°-72.5°(15° 접선 조사)로 설정함으로써 진단적 가치가 높은 영상을 획득할 수 있음을 확인하였다.

중심단어: 무릎뼈, Merchant, 접선방향, Congruence angle, Lateral patellofemoral angle, Patellofemoral index

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