The Effect of Taping on Patellar Position as Determined by Video Fluoroscopy in Patients with PFPS: A Pilot Study

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ABSTRACT

The mechanism and effect of patellar taping on patellar position has been questioned. The purpose of this pilot study was to examine the effect of patellar taping on patellar position as determined by video-fluoroscopy in patients diagnosed with patellofemoral pain syndrome (PFPS) during a closed chain squatting activity. Five females (mean age = 26.0 + 4.65 years) diagnosed with PFPS without other acute lower extremity impairments volunteered for this study. The subjects performed consecutive squats from 0 to 30 degrees knee flexion with the patella taped and without. Video fluoroscopy recorded the patellar motion in an anteroposterior view. Mediolateral patellar displacement was recorded at 0 degrees, 15 degrees, and 30 degrees of knee flexion with tape and without. At 0 degrees and 15 degrees of knee flexion in 7 out of the 10 (70%) cases the patella was re-aligned medially with tape as compared to one out of five (20%) at 30 degrees. The results of this study suggest that the McConnell medial glide taping technique may not consistently re-align the patella medially in patients with lateral tracking of the patella during a closed chain squatting activity even though pain was abated with the taping intervention.

Patellofemoral pain syndrome (PFPS) is a common lower extremity pathology found in 30% of patients seen in an outpatient orthopedic clinic.[1] PFPS has been described as any irritation, inflammation, or pain around the patellofemoral joint. However, understanding of the pathophysiology and genesis of this syndrome is still under investigation.[2-4] While the etiology of PFPS is multitudinous, mal-alignment or abnormal tracking is a frequently cited cause of PFPS.[5-9] Patients diagnosed with PFPS have been noted to report pain during functional weight-bearing activities that place the lower extremity in a dynamic and closed chain position, such as ascending and descending stairs, inclined walking, and squatting.[5,8-11] The conservative treatment for PFPS has focused on the use of anti-inflammatory medications, quadricep muscle rehabilitation, bracing, and patellar taping.[12]

The patellar taping technique as described by McConnell purports to passively correct aspects of patellar tracking, includ-

***Table 1**. Subject Characteristics (N = 6), mean, standard deviation, and range.*

	Age (yr)	Height (cm)	Weight (kg)
N = 6			
mean	26.0	164.6	58.7
SD	4.65	5.44	54.5
range	23 – 35	157.5 – 172.7	50.0 – 65.9

ing glide, tilt, and rotation.[11] This taping technique has been used to conservatively manage patellar mal-alignment, decrease pain, and enhance the quadricep muscle rehabilitation in patients with PFPS. Studies using diagnostic tools have revealed a significant response to the taping procedure with the patella re-aligning medially to the normal position.[13,14] However, evidence has shown that the patellar taping method could not withstand the stresses of a strenuous exercise program in correcting the patella medially.[13]

Shellock reported that patellofemoral mal-alignment may be found in 93% of patients diagnosed with PFPS.[15] However, little evidence has been presented to support this proposition.[8] Crossley et al performed a review of 89 relevant articles noting that there was no documented evidence supporting the use of patellar taping.[16] Patellar and femoral bony abnormalities, poor foot biomechanics, tight soft tissue structures, and a small vastus medialis oblique/vastus lateralis (VMO/VL) ratio may all contribute to patellofemoral mal-alignment. Previous studies have used radiographs, computed tomography (CT), and magnetic resonance imaging (MRI) to examine patellar tracking in a variety of angles and situations.[13-15,17-19] None of these investigations have been performed during a dynamic interaction of the joint components during normal weight-bearing activities.

The fluoroscope is a diagnostic tool that has the capability to examine the patellofemoral joint functioning in a dynamic, weight-bearing activity. A study[20] using the fluoroscope examined patellar tracking during treadmill walking. Results revealed a tracking pattern that is very different from that which was assumed from the anatomy of the knee and recorded in other studies that measured only passive motion or non-weight-bearing active motion of the knee.[20]

The current state of knowledge and research regarding the effectiveness of patellar taping with the diagnostic abilities of fluoroscopy in ADL is very limited. Therefore, the purpose of this study is to examine the effect of patellar taping on patellar position as determined by video-fluoroscopy in patients diagnosed with PFPS during a closed chain squatting activity.

METHODS

Subjects

The study group consisted of five female volunteers diagnosed with PFPS at an outpatient orthopedic clinic by an orthopedic surgeon (Table 1). Individuals were excluded if they had acute impairments at the tibiofemoral joint or one joint above or below the patellofemoral joint. In addition, if female patients tested positive on the pregnancy exam, they were excluded. The participants completed a subject-screening questionnaire. Subjects read and signed an informed consent document that was in accordance with Andrews University's and Kettering Medical Center's institutional review boards.

Equipment / Instrumentation

The research was done using Leukotape™ (Don Joy, Inc, Carlsbad, CA) with the application of the McConnell taping technique. The research was performed at an imaging center (Dayton Medical Imaging, Centerville, OH). A custom-designed subject-screening questionnaire was used to include volunteers in this research study.

The Siemens Polydoros 5 x 80 microprocessor-controlled, multipulse 50 kW X-ray generator video fluoroscope (Siemens Corporation, New York, NY) was used to record patellar tracking during consecutive mini-squats. A certified technician recorded the fluoroscopic image. A standard goniometer (Jamar, Jackson, MI) was used to measure knee joint range of motion to a specific range (0 - 30^{o} knee flexion) during the mini-squat activity. Adobe Premiere 5.0 (Adobe Systems, Inc, San Jose, CA) and Scion Image (Scion Corporation, Frederick, MD) motion software analysis systems were used on an IBM compatible processor to enhance the image and quantify the amount of patellar displacement.

Protocol

.The subjects stood on the fluoroscope platform with their feet shoulder width apart. The subject's arms rested comfortably at their side with palms facing posteriorly resting upon the fluoroscope table (Figure 1). Subjects squatted to 30^{o} of knee flexion and then back to the starting position (0^{o} of knee flexion). The hip and ankle joint were observed for smooth and appropriate movement. To set the desired mini-squat knee ROM, an investigator stood beside the subjects' involved knee with a goniometer and measured knee flexion. When subjects reached 30^{o} of knee flexion, a second investigator placed a marker on the fluoroscope table slightly touching the subject's extended right third finger.

The marker was used to signal to the subjects that they had reached 30^{o} of knee flexion. Another marker, 21 millimeters (mm) in length was placed slightly superior to the patellofemoral joint on the fluoroscope table providing the reference scale for future measurement. The subjects then extended their knees to the starting position. The subjects were given as much time as needed to practice and familiarize themselves with the mini-squat procedure.

After the practice session, the subjects stood on the fluoroscope platform and performed five consecutive mini-squats to 30^{o} of knee flexion. The fluoroscope was placed anterior to the knee diagnosed with PFPS, giving a frontal plane image of the patella's medial and lateral glide. A metal rod was placed in the field of the fluoroscopic image superior to the patellofemoral joint once the subjects reached 0^{p}, 15^{o}, and, 30^{o} knee flexion. The purpose of this device was to identify the knee's position during the data analysis.

After the first five consecutive mini-squats, the patient sat down and the investigator cleaned the subjects' patellar region on the involved knee. A licensed physical therapist trained in the McConnell taping applied the medial glide taping technique to the involved knee. The subjects performed five more consecutive mini-squats while the involved knee was being imaged fluoroscopically.

Data Analysis

After the testing procedure, the fluoroscopic images were computerized and enhanced through Adobe Premiere 5.0 (Adobe Systems, Inc, San Jose, CA). The images were then converted over to another motion software analysis system, Scion Image (Scion Corporation, Frederick, MD), where the images were enhanced and patellar displacement was measured. Reference points were identified digitally in all of the mini-squat repetitions at 0^{o}, 15^{o}, and 30^{o} of knee flexion. The reference marker as described above was used to set the measurement scale for each specific image. Patellar diameter was calculated in millimeters by marking the most medial and lateral aspects of the patella. The mid-section of the patella was calculated in millimeters by dividing the patella's diameter in half. The medial and lateral femoral epicondyles were marked digitally. The difference of the distance in millimeters from the marker at the mid-section of the patella to the marker at the medial and lateral femoral epicondyles was the patellar displacement. The average patellar displacement for all five repetitions at the three knee positions with the involved knee taped and not taped was used as the

final measurement for each subject.

Statistical Analysis

A repeated measures ANOVA was performed initially. However, in analyzing the statistics, low power and an unsatisfactory equal variance directed our analysis to compare and contrast subjects individually. The data obtained was compared and contrasted in relation to the individual's average medial/lateral displacement and knee position.

RESULTS

At 0° knee flexion, video fluoroscopic examination revealed that three out of the five (60%) subjects presented with lateral patellar displacement before tape intervention. At 15° knee flexion, three out of the five (60%) subjects presented with lateral patellar displacement before intervention. At 30° knee flexion, two out of five (40%) subjects presented with lateral patellar displacement before intervention (Table 2).

To examine the effects of taping on the involved knees, a comparison was made between the baseline measurements from each of the subject's baseline fluoroscopic images taped and non-taped at 0°, 15°, and, 30° of knee flexion. At 0° knee flexion, four out of five (80%) subject's patella were re-aligned medially with tape. The average patellar displacement for all five subjects at 0° was 1.68 mm medially (Table 3, Fig. 2A). At 15° knee flexion, three out of five (60%) subject's patella were re-aligned medially with tape. The average patellar displacement for all five subjects at 15° was 0.92 mm medially (Table 3, Fig. 2B). At 30° knee flexion, four out of five (80%) subject's patella were re-aligned laterally with tape. The average patellar displacement for all five subjects at 30° was 0.70 mm laterally (Table 3, Fig. 2C).

Table 2. *Mean patellar displacement non-taped at 0°, 15°, and 30° knee flexion.*

Subject	Knee Flexion (degrees)	Patellar Displacement (mm)
1	0	3.54
	15	5.47
	30	3.24
2	0	-1.14
	15	-0.85
	30	-2.05
3	0	2.05
	15	-4.48
	30	-4.25
4	0	-1.75
	15	0.80
	30	-3.75
5	0	7.54
	15	7.67
	30	6.44

(+) values = lateral displacement
(-) values = medial displaceme

Table 3. *Mean patellar displacement between taped and non-taped at 0°, 15°, and 30° knee flexion.*

Subject	Knee Flexion (degrees)	Patellar Displacement (mm)
1	0	-2.98
	15	-1.60
	30	0.68
2	0	-1.77
	15	-4.74
	30	0.39
3	0	-0.60
	15	0.58
	30	1.12
4	0	1.75
	15	-0.22
	30	2.22
5	0	-4.92
	15	1.39
	30	-0.83

(+) values = lateral displacement
(-) values = medial displacement

In summary, the effectiveness of the taping procedure was evident in only eight out of the fifteen (53%) cases moving the patella medially at 0°, 15°, and 30° of knee flexion. Although, at 0° and 15° of knee flexion in seven out of the ten (70%) cases, the patella was re-aligned medially with tape as compared to one out of five (20%) at 30°.

DISCUSSION

PFPS is a common lower extremity pathology affecting many patients seen in outpatient orthopedic clinics today. Etiological factors that can cause anterior knee pain or patellofemoral pain are multitudinous in nature. They include small VMO/VL ratio, abnormal foot biomechanics, tight soft tissue structures, and patella and/or femoral bony abnormalities. Patellar malalignment and the subsequent inappropriate tracking pattern of the patella may result from any of the aforementioned factors. However, there is usually a combination of factors that cause patellofemoral pain, which make the assessment of this patient population all the more difficult. Patients suspected of having a maltracking patella might be treated with a variety of conservative treatment methods. One such method is patella taping as described by McConnell.[21]

There is uncertainty in the current literature as to whether the reduction in patellofemoral pain with McConnell taping is due to the re-alignment of the patella or neural inhibition from the tape via large fiber input.[22] To our knowledge, our study is the first to measure patellar displacement in a dynamic weightbearing situation using the McConnell taping technique.

In a study by Somes et al,[22] nine subjects with PFPS were x-rayed in the open kinetic chain (OKC) and closed kinetic chain (CKC) at 45° of knee flexion with and without tape. The results did not show a significant difference in the patellofemoral congruence angle (medial glide) with tape during either the OKC or the CKC. The five knees taped in our study did not show a consistent change, medially or laterally, with the taping technique. However, it should be noted that the measurements were taken at different degrees of knee flexion. At 45° of knee flexion, the tape may be less significant in moving the patella as it is already seated in the trochlear groove of the femur.

In a study by Bockrath et al,2312 subjects with anterior knee pain syndrome using McConnell taping showed a significant reduction (50%) in pain level as revealed by the visual analog scale. This reduction in pain, however, did not correlate to a significant change in patella position as seen in the patellofemoral congruency and patella rotation angles. Subjects in Bockrath's study taped their own patellae, but had been trained to do so by a physical therapist trained in the McConnell taping technique. However, no instruction or assessment was provided in taping during the testing procedures to enable the investigators to determine whether the reduction in pain was correlated to a significant change in patella position.

Bockrath et al[23] suggested that the reduction in pain may be related to sensory input from the tape itself. However, it should be noted that the patella was measured at 45° of knee flexion during an OKC isometric quadricep contraction. It is essential to examine the patella within the first 30° of knee flexion because it is here where the quadricep and other soft tissue structures are the main control of patellar position and the patella has a tendency to be unstable.[24] After 30° of knee flexion, the patella is seated in the trochlear groove and patellar alignment is primarily maintained by the bony contour of the femur.[24]

Each subject in our study was diagnosed with lateral tracking of the patella by a local orthopedic physician. We found that the medial glide technique did not realign all patellae medially at each degree of knee flexion (0°, 15°, and 30°). These results suggest that the McConnell medial glide taping technique may not always keep the patella aligned medially in a dynamic weight-bearing situation. Dupuy et al,[25] examined 20 knees in 18 patients with anterior knee pain

with kinematic CT. Lateral patellar translation during active knee extension (60º-30º) was found in 8 of 20 knees. Their study demonstrated that only 40% of patients tracked laterally between 60º and 30º knee flexion.

Subjects in Dupuy's study were suspected to have patellofemoral tracking disorders solely based upon their common symptom of anterior knee pain. The investigators stated that one of the drawbacks of their study was the variety of diagnostic problems that may cause the common symptom of anterior knee pain aside from tracking abnormalities.

Larsen et al[13] performed a study that radiographically determined the effectiveness of the McConnell medial glide technique pre and post-exercise using 20 healthy subjects. The results showed a significant response to the taping procedure with the patella moving medially from baseline in 85% of the subjects prior to exercise. Although pre-exercise data showed a significant difference between radiographs after taping, post-exercise radiographs showed no significant difference between the pre-exercise data. This suggests a breakdown in the tape with exercise. These results were recorded in partial weightbearing with 40º of knee flexion. Again, 40º may not be the ideal angle to measure abnormalities in patellar tracking as the patella is seated in the trochlear groove at this degree of knee flexion.

The evidence that suggests that patellar taping does not have a lasting effect on patellar position leads to the consideration that there is another mechanism related to the subjective report of pain relief. Cowan et al[11] reported that patellar taping altered the temporal characteristics of the vasti musculature in people with PFPS. It was concluded that the temporal characteristics of vastus medialis obliquus and vastus lateralis activation was altered when participants with PFPS treated with patellar taping completed a stair stepping task compared to controls and placebo groups.[11] Powers et al[10] report that patellar taping may have an effect on gait and joint motion in subjects with PFPS. It was found that there was a significant increase in stride length during ramp ascent in addition to a 78% reduction in average pain. It was also noted that there was a small but significant increase in the loading response knee flexion for all groups. The authors concluded that the abatement of pain with the taping technique may lead to increased willingness for patients to load the knee allowing for increased quadriceps activity, shock absorption, and tolerance to increased patellofemoral joint reaction force.[10]

Our results did not coincide with our original hypothesis that the taping procedure would move every patella medially in each degree (0º, 15º, 30º) of knee flexion. Four out of five (80%) patellae were re-aligned medially with tape at 0º. During static standing posture with knees fully extended, there is normally no need for quadricep activity to remain upright. However, if one is accustomed to standing with the knees in hyperextension, then there may be some quadricep activity at 0º knee flexion. We asked our subjects to stand erect while we measured 0º knee flexion, but did not take into account possible quadricep activity which directly affects patellar position. Some subjects may have had quadricep activity at 0º knee flexion while others did not. This may have re-aligned the patella laterally in subject [4].

When subjects reached 15º knee flexion, only three subjects remained medial with the tape as compared to no tape. Surprisingly, only one subject's patella remained medial with tape at 30º knee flexion. Unlike the situation that exists at 0º knee flexion, quadricep activity is prerequisite at 15º and 30º to effectively control the flexion moment at the knee. Patients with lateral tracking abnormalities often have tight lateral structures (lateral retinaculum, iliotibial band) and a small VMO/VL ratio. Thirty degrees of knee flexion requires greater quadricep force than 0º or 15º, and with a small VMO/VL ratio, the patella is often pulled laterally. This may have indeed been the case in our study. It would have been interesting to see

what the EMG activity of the VL and VMO were during this study. Not only are small VMO/VL ratios seen in patients with patellofemoral pain, but inappropriate VMO/VL firing patterns are often seen as well. The VMO is often delayed.26 This combination of relative VMO weakness and altered firing pattern in this patient population may be one reason why four out of five subjects patellae remained lateral at 30º with the tape.

The fluoroscopic anteroposterior (AP) view utilized does not permit measurement of patellar tilt in the transverse or sagittal planes, nor is it sensitive to the small amount of axial rotation that occurs at the knee. However, mediolateral (ML) patellar displacement was the only measurement of concern in our study as the medial glide technique was the only technique used. Therefore, the fluoroscopic AP view was the ideal view for this study to measure ML displacement.

CONCLUSION

We recognize that this study has limitations in relating these findings to the larger patient population with patellofemoral pain. Our sample size consisted of five female patients, none of which were overweight or adolescent. These limitations were accepted, however, to construct some initial data and to serve as a stepping stone for further research in this area. We would recommend that future studies use a digital fluoroscope for cleared imaging, larger sample size including male and female patients, and a control group without PFPS.

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