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The Effect of Patellectomy on Knee Function *

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ABSTRACT: Thirty-three patients were evaluated after patellectomy for subjective complaints, objective physical findings, quadriceps strength, and knee motion during activities of daily living. Partial and complete patellectomy caused an equal loss of active and passive range of motion. Complete patellectomy resulted in greater ligament instability, quadriceps atrophy, and loss of quadriceps strength compared with partial patellectomy. Complete patellectomy caused a reduction in the degree of stance-phase flexion during level walking and negotiating stairs.

There are numerous reports in the literature on the results of patellectomy^{1,2,4,11,15,16,17}. However, good quantitative measurements of strength and movements of the patellectomized knee during activity are lacking. If the mechanics of the knee joint are significantly affected by patellectomy, prosthetic replacement may be needed on occasion, either separately or in combination with total knee-replacement procedures.

Studies of the strength of the quadriceps have in the main been based on manual evaluation and maximum weight-lifting measurements. Different degrees of loss of quadriceps strength after patellectomy have been reported^{13,15,16}.

Motion studies after patellectomy have focused mostly on active or passive motion in the sagittal plane during clinical examination, and loss of extension and of flexion has been reported as percentage of the normal, but little is known about the effects of patellectomy on the function of the knee during daily activities or of the contribution of the patella to stability of the knee. This report details the effects of partial and complete patellectomy on the following: the strength of the quadriceps, the motion used for the activities of daily living, and the functional ability of the patellectomized knee.

Materials and Methods

Thirty-seven patellectomized knees (twenty-six complete and eleven partial) in thirty-three patients were studied. In the group with complete patellectomy, there were sixteen men and nine women with an average age of

40.3 years and an average follow-up of 63.7 months. There were nineteen men and fourteen women in the entire series. The age range was from twenty-two to seventy-two years, with an average of 42.9 years. Four patients had bilateral operations: one had bilateral complete patellectomy, two had bilateral partial patellectomy, and one had a complete patellectomy on the left and partial patellectomy on the right. Partial patellectomy was defined as removal in the anteroposterior plane of at least one-third of the patella with the remaining fragment having an anteroposterior thickness great enough to maintain an effective lever arm. Information from operative reports was not sufficient to determine the exact surgical technique used in total patellectomy. Therefore, comparisons of the results according to surgical technique could not be made. The longest postoperative follow-up was 192 months, with an average of 52.6 months and a minimum of twelve months. Almost all patients felt that they did not improve significantly after the first year following surgery. All patients with unilateral lesions returned for goniometric motion studies. Of this group, there were fourteen men and eleven women, with twenty complete and eight partial patellectomies. The average age of this group was forty-five years, with an average follow-up of 57.5 months.

Traumatic fracture of the patella was the reason for surgery in nineteen of the thirty-seven knees; twelve of the twenty-six complete patellectomies and seven of the eleven partial patellectomies were for fractures. In the other eighteen knees, the indication for surgery was either patellofemoral arthritis or chondromalacia of the patella.

Patients were evaluated with reference to their activity level, pain at rest, pain with activity, ability to squat, negotiation of rough ground, ability to go up and down stairs, and the distance they could walk. They were examined for abnormalities of gait, pain on patellar compression or on subluxation, pain with motion, synovial thickening, active and passive flexion and extension, standing tibiofemoral angle, and quadriceps atrophy (as measured by the circumference of the thigh fifteen centimeters above the knee). Ligament stability was assessed by one examiner, who gauged the stability of the medial and lateral collateral ligaments, the anterior and posterior drawer signs, and the stability of the knee in medial and lateral rotation. Each of these parameters was compared with that of the opposite (normal) knee and graded on a scale of one to four. Grade One was the normal (no difference); Grade Two was a mild difference (one to four millimeters of the specific measurement); Grade Three was

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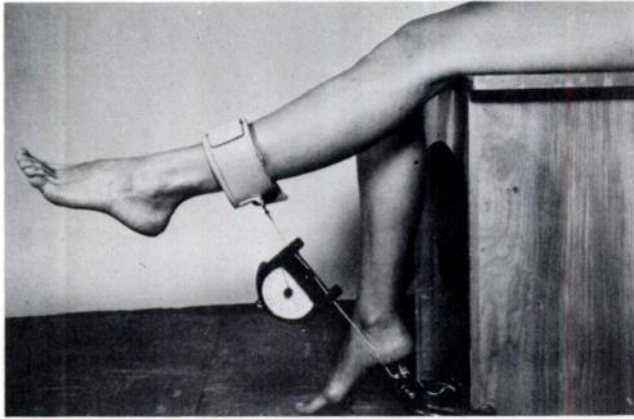


FIG. 1
Isometric cable tensiometer.

moderate instability (five to eight millimeters); and Grade Four was severe instability (greater than eight millimeters). These six parameters were then averaged, giving each knee operated on a "stability score".

Using an isometric cable tensiometer (Fig. 1), the strength of the quadriceps (patellar tendon tension) was measured at 20 degrees of flexion. Three maximum contractions were recorded for each knee. The patients were given adequate time for relaxation between each contraction. The average of these three contractions was used to calculate the quadriceps strength^{6,10}.

A three-plane electrogoniometer attached to a three-channel dynograph was used to graphically record knee motion as previously described^{5,8}. Both knees of each patient were studied after the patient had become accustomed to the electrogoniometer. The patients used their normal gait as they walked through a measured level course, ascended and descended a two-step twenty-centimeter rise, and sat down and stood up from a standard straight-backed chair. The measurements of ten steps were used to compute average stance-phase flexion, swing-phase flexion, abduction-adduction, internal-external rotation, cadence, and stride length while the patients walked the level course. The data on climbing four steps up and descending four steps down the riser were used to compute average flexion, abduction-adduction, and rotation used in ascending and descending stairs. Two recordings were made to

compute the average amount of knee flexion used in sitting and standing.

Results

Patients who had a partial patellectomy had less pain with activity and less pain at rest, could squat more easily and walk farther, had fewer problems negotiating stairs and rough ground, and had a higher activity level than patients with a complete patellectomy; however, the differences were not significant at the $p < 0.05$ level.

No significant differences were found in the activities of daily living when comparisons were made between the patients who had surgery for fractures and those who had surgery for other reasons.

Clinical instability occurred in four of eleven knees with partial and nineteen of twenty-six knees with complete patellectomy; the degree of instability was greater in the knees with complete patellectomy ($p = 0.05$).

The average range of motion for knees with partial patellectomy was 122 degrees and for those with complete patellectomy it was 117 degrees, both averages being lower than the average of 134 degrees for the normal knee (Table I). After elimination of the patients who had bilateral surgery (three complete and five partial patellectomies), comparison of the side operated on with that not operated on showed significant loss of motion after complete and after partial patellectomy ($p = 0.005$). All six knees with partial and fifteen of twenty-three knees with complete patellectomy exhibited a loss in range of motion compared with normal.

Quadriceps atrophy (thigh circumference) averaged 2.2 centimeters in knees with complete patellectomy ($p = 0.001$, Table I), and in cases of partial patellectomy, 0.8 centimeter (not significant). The quadriceps strength as measured in knees with complete patellectomy averaged sixty-two kilograms less than normal (Table I), a 49 per cent reduction of the strength of the normal extensor mechanism ($p \leq 0.001$). Knees with partial patellectomy had a gain of seven kilograms, or 5 per cent (not significant), compared with normal. Only six patients with partial patellectomy with a normal opposite knee were tested.

Knee motion during walking was evaluated in the

TABLE I
AVERAGE MEASUREMENTS OF RANGE OF MOTION, ATROPHY, AND QUADRICEPS FORCE FOR NORMAL, PARTIALLY PATELLECTOMIZED, AND COMPLETELY PATELLECTOMIZED KNEES

	Normal (29)	Partial Patellectomy (11)	Complete Patellectomy (26)	Partial Patellectomy vs. Normal Knee* (6)	Complete Patellectomy vs. Normal Knee* (23)
Range of motion	134.111	121.818	117.308	-17.525†	-17.500†
Quadriceps measurement (cm)	46.741	48.546	43.827	-0.833	-2.239‡
Quadriceps force (kg)	131.839	143.673	78.528	7.433	-61.532‡

* Same patient.

† $p \leq 0.005$.

‡ $p \leq 0.001$.

TABLE II
AVERAGE GONIOMETRIC MEASUREMENTS FOR NORMAL, PARTIALLY PATELLECTOMIZED, AND COMPLETELY PATELLECTOMIZED KNEES

	Normal (22)	Partial Patellectomy (8)	Complete Patellectomy (20)	Partial Patellectomy vs. Normal Knee* (4)	Complete Patellectomy vs. Normal Knee* (18)
Swing-phase flexion	55.750	52.450	50.180	-4.825	-4.272
Stance-phase flexion	14.341	10.163	7.220	-5.775	-6.950 [†]
Abduction-adduction	11.686	13.275	10.325	0.150	-2.605
Rotation	13.450	13.613	13.835	0.275	0.294
Stairs up — flexion	71.195	64.063	52.920	12.000	-18.228 [‡]
Stairs up — abduction-adduction	16.282	17.850	13.540	-0.975	-2.794
Stairs up — rotation	13.323	11.000	12.730	1.625	0.006
Stairs down — flexion	70.295	63.125	53.920	-18.375	-16.183 [‡]
Stairs down — abduction-adduction	15.323	15.913	13.510	-3.225	-2.239
Stairs down — rotation	15.750	13.500	14.295	-1.350	-1.650
Sit-stand flexion	72.995	79.625	63.725	-4.750	-8.800

* Same patient.

[†] $p \leq 0.01$.

[‡] $p \leq 0.05$.

knee operated on and in the opposite, normal knee (Table II). We found that the excursion did not differ from normal for the group with partial patellectomy. Differences might have been evident had more of the patients who had partial patellectomy returned for the electrogoniometric study. Significant differences were found when the group with complete patellectomy was compared with normal. The knees with complete patellectomy used less stance-phase flexion (average, 7 degrees; $p \leq 0.001$), less flexion going up stairs (average, 18 degrees; $p \leq 0.01$), and less flexion going down stairs (mean, 16 degrees; $p \leq 0.05$).

Discussion

The only significant deviation from normal found after partial patellectomy was an average loss of 18 degrees of range of motion. The same loss of motion was encountered after complete patellectomy. This finding suggests that the patella is not necessary to maintain the range of motion of the knee. Other factors, such as the effect of the initial injury on the soft tissues of the joint and post-operative immobilization, probably were the main causes of the loss of motion.

O'Donoghue and associates, using a spring gauge, found no differences in the strength of the quadriceps on the right and left in normal subjects. They reported a 30 per cent loss of strength in knees with patellectomy. Stougård, using maximum weight-lifting from the position of 90 degrees of flexion to full extension, found that one-third of patellectomized knees had less than 50 per cent of the strength of extension of the normal (contralateral) side. Kaufer, using extremities from cadavera, found that after patellectomy, depending on the type of tendon repair, a 15 to 30 per cent increase in the force through the extensor mechanism was needed to fully extend the knee. The 49 per cent reduction in strength of the extensor mechanism found in the present study of twenty-four completely patel-

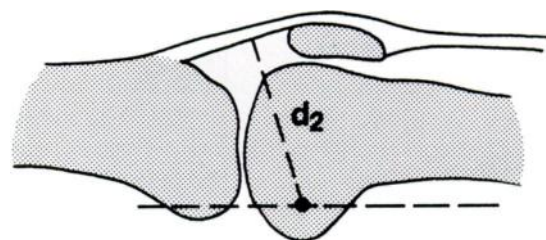


FIG. 2

d_2 — normal extensor mechanism lever arm with intact patella.

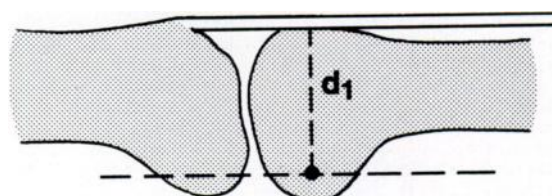


FIG. 3

d_1 — decreased extensor mechanism lever arm with complete patellectomy.

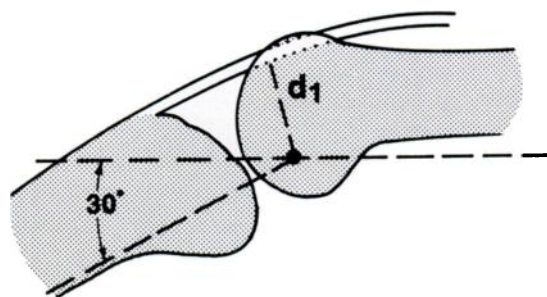


FIG. 4

d_1 — decreased extensor mechanism lever arm with flexion.

lectomized knees is a greater loss than has been previously reported. Although the loss of quadriceps mass (average, 2.2 centimeters) is important, we believe that the primary

cause of the weakness was the reduction of the lever arm (the perpendicular distance from the applied force through the extensor mechanism to the center of the axis of rotation of the knee [Fig. 2]) produced by loss of the patella (Fig. 3). Restoration of this lever arm in cadaver studies greatly reduced the force needed for extension⁷.

Instability was greater in the knees that had had a total patellectomy. Loss of an apparent stabilizing effect of the patella may complicate prosthetic replacement of the knee unless the needed stability can be restored by some other means.

The measurements of knee motion during level walking, as determined for the normal knees in this study, were similar to those recorded in other reports^{3,8,9,12,14}. However, the patellectomized knees lost almost 50 per cent of the excursion in stance-phase flexion (average, 7.0 degrees). After a patellectomy, when the knee flexes the patellar tendon will sink into the intercondylar notch and the length of the lever arm of the extensor mechanism is reduced (Fig. 4). This causes relative quadriceps insufficiency, leading to inability to support the loaded flexed knee. This mechanism may also explain the loss of flexion excursion seen when the patellectomized knee is loaded and the patient is going up and down stairs.

Although the present report is concerned only with cases of patellectomy, we believe that the use of an electrogoniometer is an important method that may be applied

not only to problems involving the patella but also to those involving other structures at the knee. For example, this instrument can be used to evaluate ligament injury and repair and results after different types of total knee arthroplasty or reconstruction.

If a normal range of motion of the knee proves to be a critical component of a patient's result after prosthetic replacement, then restoration of the excursion and power of the extensor mechanism will be necessary as part of the operation. Preservation of the lever arm afforded by the patella and vigorous quadriceps rehabilitation will then contribute to a stronger, more stable knee and reduce the stresses on the prosthetic components and bone-cement interface.

Summary

1. The loss of range of motion after complete or partial patellectomy averaged 18 degrees.
2. A greater percentage of patients had instability and a greater degree of instability was evident after complete than after partial patellectomy.
3. There was quadriceps atrophy (average, 2.2 centimeters) and a 49 per cent reduction in the strength of the extensor mechanism after complete patellectomy.
4. Complete patellectomy caused stance-phase flexion excursion to be reduced both for level walking and for going up and down stairs.

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