

MECHANICAL RESISTANCE OF THE PATELLAR LIGAMENT AFTER REMOVAL OF THE MIDDLE THIRD THROUGH EITHER ONE LONGITUDINAL INCISION OR TWO MINI-TRANSVERSE INCISIONS

Leandro Calil De Lazari¹, Cleber Antonio Jansen Paccola²

ABSTRACT

Objective: To evaluate the resistance and regeneration of the patellar ligament after harvesting a graft for reconstruction of the anterior cruciate ligament, using the traditional technique of a single longitudinal skin incision or a technique of two transverse mini-incisions, in sheep. **Methods:** Ten sheep were used. In the right knee, we removed the graft using the traditional method, and in the left knee, using the two-incision method. The animals were observed for six months. The specimens (patellar ligament, tibia and patella) were adapted to the mechanical test machine for ligament resistance tests. **Results:** No difference was found be-

tween the two proposed techniques in relation to the regeneration and resistance of the patellar ligament. However, we observed that shortening of the patellar ligament occurred in both groups, and that suturing of the superficial fascia of the patellar ligament did not influence the regeneration of the patellar ligament, according to the histology. **Conclusion:** The technique using two incisions in the skin presents the same patterns of regeneration and resistance of the remaining patellar ligament as shown by the traditional technique of a single, longitudinal incision.

Keywords – Anterior cruciate ligament; Patellar ligament; Sheep

INTRODUCTION

Reconstructions of the anterior cruciate ligament (ACL) using the middle third of the patellar ligament as a graft have produced good functional results. However, persistent pain at the graft harvesting site, anterior sensitivity disorders in the knee and difficulty in kneeling down are problems encountered by 40 to 60% of patients who undergo ACL reconstruction when the traditional technique for harvesting a patellar graft, through a single longitudinal incision, is used⁽¹⁾.

Minimally invasive techniques are being developed in many areas of surgery, with the aims of diminishing the aggression to soft tissues and enabling rehabilitation as early and as painlessly as possible, along with improving the esthetic appearance of the scar.

Two less invasive techniques for harvesting grafts from the patellar ligament for ACL reconstruction can be seen in the literature: one described by Kartus *et al*⁽¹⁾

through two longitudinal mini-incisions and the other, described by Carneiro *et al*⁽²⁾ and Tsuda *et al*⁽³⁾, through two transverse mini-incisions. Both of them have the aim of diminishing the aggression to soft tissues and avoiding injury to the infrapatellar branch of the saphenous nerve and anterior pain in the knee.

There has been some concern regarding the effect of suturing the superficial fascia for regeneration of the remaining ligament. Shortening of the tendon has been reported by several authors.

Adam *et al*⁽⁴⁾ harvested a graft from the patellar ligament and did not close up the flaw left by its removal, but sutured the superficial fascia. They reported that shortening of the patellar ligament occurred in all their cases.

Krosser *et al*⁽⁵⁾ analyzed two groups: one in which the flaw left by harvesting the graft from the patellar ligament was closed up; and another in which the flaw was not closed. They concluded that there was no sig-

1 – Orthopedist. PhD student at the Ribeirão Preto School of Medicine, University of São Paulo (USP).

2 – Professor Titular of the Department of Biomechanics, Medicine and Rehabilitation of the Locomotor Apparatus, Ribeirão Preto School of Medicine, University of São Paulo (USP).

Work performed in the Department of Biomechanics, Medicine and Rehabilitation of the Locomotor Apparatus, Ribeirão Preto School of Medicine, University of São Paulo (USP). Correspondence: Leandro Calil De Lazari, Rua Dr. Álvaro Costa Couto 50, apto. 1201, 14015-140 Ribeirão Preto, SP – E-mail: calil.delazari@hotmail.com

We declare that there is no conflict of interests in this article

nificant difference between the two groups. They also reported that shortening of the patellar ligament occurred in both groups.

There are few reports in the literature regarding lesions of the patellar ligament after harvesting a graft. Lee *et al*⁽⁶⁾ reported some cases of postoperative complications in the patellar ligament, with rupture of the ligament after removal of the graft. However, it can be asked whether the viewing difficulties that are inherent to the technique of two mini-incisions for harvesting the patellar graft might cause removal beyond what would be desired, thereby weakening the remaining part of the ligament. There is also the question of whether suturing of the superficial fascia (which is only possible when using the classic technique of a single longitudinal incision) has any influence on the regeneration of the ligament^(1,7,8).

Our aim in this study was to analyze the mechanical resistance of the remaining patellar ligament, after harvesting a graft from its middle third for ACL reconstruction, either using the traditional technique (single longitudinal incision) or two transverse mini-incisions.

METHODS

Ten shorn adult ewes of undefined breed, weighing 45 to 55 kg, were used.

From the right knee, a bone-tendon-bone graft was harvested in the traditional manner, by means of a longitudinal incision from the lower pole of the patella to the anterior tuberosity of the tibia. The superficial fascia was sutured and the remaining thirds of the ligament were brought together using separate stitches. The incision in the left knee consisted of two mini-incisions that followed the width of the patella and the anterior tuberosity of the tibia (Figures 1 and 2).

In both techniques, the lateral and medial extremities of the patellar ligament were marked out using stitches of 3-0 nylon thread, so that these points could be located more easily later on. All the ligaments were measured, noting the length and the proximal, medial and distal circumferences, using a special device that was specially developed for this purpose. An example of this measurement model is shown in Figure 3 and the values are shown in Table 1.

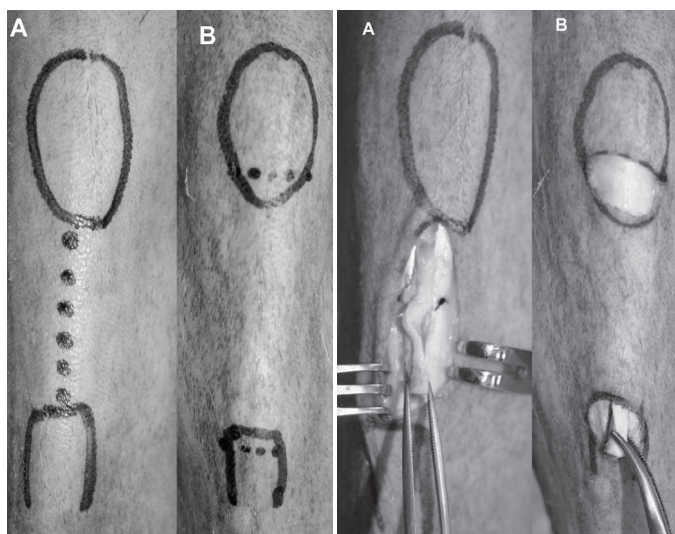


Figure 1 – Anterior view of the knee. The dotted line represents the planned incisions. A) Single longitudinal incision. B) Two transverse mini-incisions.

Figure 2 – Anterior view of the knee during the operation. A) Traditional incision, with graft already individualized and tibial bone block already raised. B) Two incisions. The harvesting went from distal to proximal.

In the two-incision technique (surgery), the circumference of the medial region of the patellar ligament was considered to be equal to the same circumference on the contralateral side, given that these measurements were on the same animal. The animals remained free to move and support their own full weight.

Six months later, the animals were sacrificed (this length of time was suggested by Picado *et al*⁽⁷⁾). The scars were photographed and the patellar ligaments were isolated and measured, following the markings of the nylon stitches. The patella, patellar ligament and tibia were removed from the animals as a single block, for mechanical tests and histological analysis.

In an alternate manner, five animals were chosen sequentially for histological analysis and five for the mechanical tests.

The mechanical traction test was performed using a test machine*. The tests used were the following: traction of the patellar ligament until is rupture, maximum force for breaking the ligament and maximum tension in the ligament at the time of rupture (Figure 4).

The histological analysis was performed by analyzing the portion halfway between the patella and tibia. The sections were stained using hematoxylin-eosin and were examined at a magnification of 25 times.

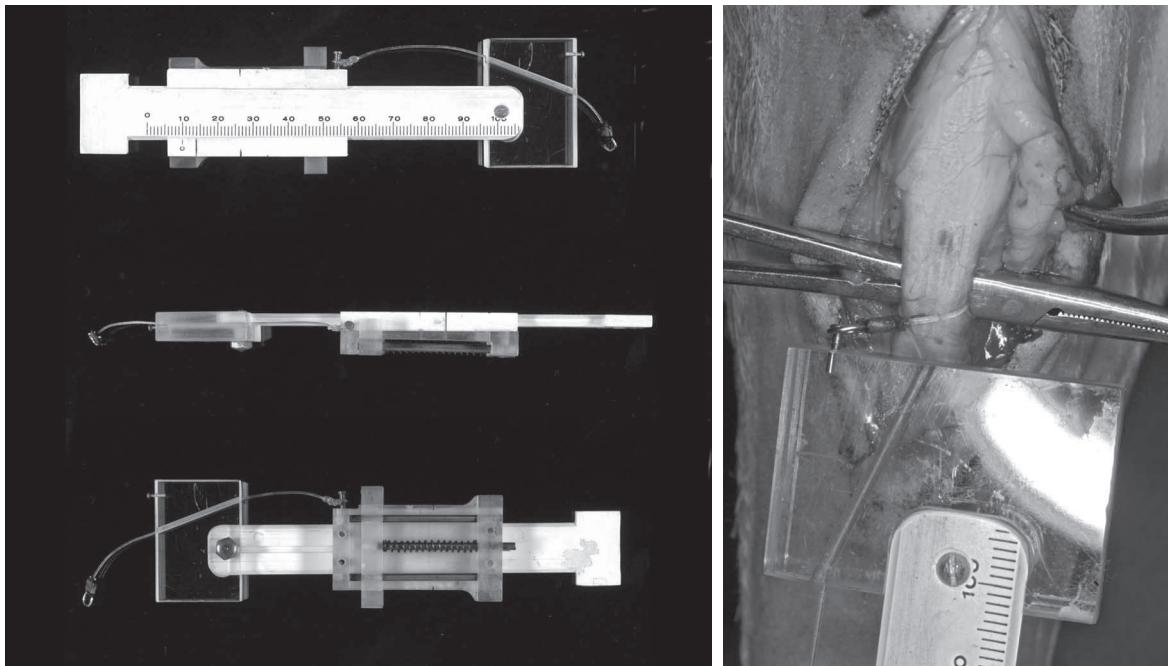


Figure 3 – View of the instrument for measuring the circumference and the corresponding measurement during the operation.

Table 1 – Means for the circumference, area and length of the patellar ligament

Traditional technique, mean value	Surgery	Sacrifice
Upper circumference (mm)	20.18	30.36
Middle circumference (mm)	19.55	29.45
Lower circumference (mm)	20.23	29.55
Longitudinal length (mm)	54.64	35.27
Upper area (mm ²)	32.60	74.40
Middle area (mm ²)	30.49	69.91
Lower area (mm ²)	32.74	70.25
Two-incision technique, mean value	Surgery	Sacrifice
Upper circumference (mm)	19.77	29.09
Middle circumference (mm)	19.55	29.45
Lower circumference (mm)	19.55	28.00
Longitudinal length (mm)	55.27	34.73
Upper area (mm ²)	31.18	68.36
Middle area (mm ²)	30.49	69.91
Lower area (mm ²)	30.46	63.49

RESULTS

The statistical analysis was performed using the non-parametric Wilcoxon test, with analysis on the deformation, maximum force and the maximum tension at the moment of graft rupture. We obtained p-values greater

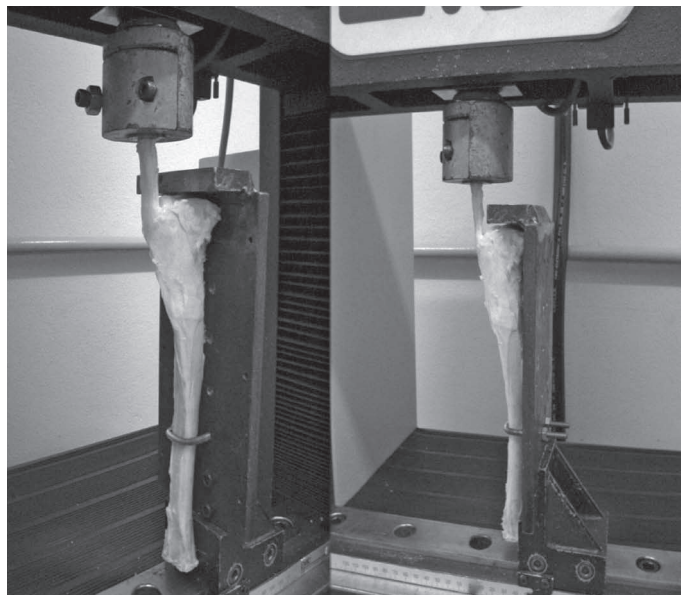


Figure 4 – View of the extracted block of the patella, patellar ligament and tibia in the test machine (*Model EMIC DL 10000, São José dos Pinhais, Curitiba, PR, Brazil).

than 5% in all of the analyses, which indicates that there was no significant difference between the two groups (Table 2).

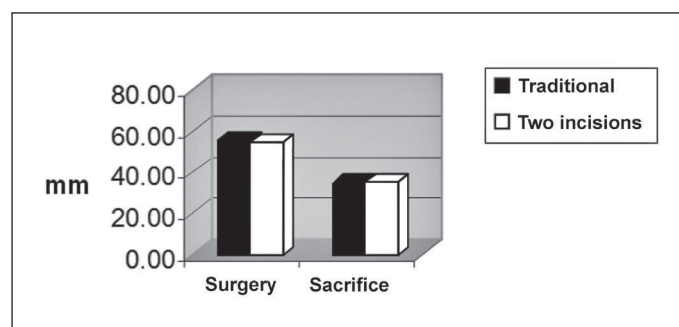
In the analysis on the area and longitudinal length of the patellar ligament at the times of the surgery and sacrifice, the p-value was greater than 5%, which indicated that there was no significant difference between the groups.

Table 2 – Statistical analysis on deformation, maximum force and maximum tension

	Mean	Standard deviation	Coefficient of variation	Median	p value
Deformation	(%)	(%)	(%)	(%)	
Traditional	51.19	19.48	38.05	42.95	0.06
Two incisions	60.23	15.78	26.20	57.06	
Maximum force	(Newton)	(Newton)	(Newton)	(Newton)	
Traditional	2221	843	37.99	2058	0.59
Two incisions	2415	450	18.64	2232	
Maximum tension	(Pascal)	(Pascal)	(Pascal)	(Pascal)	
Traditional	34532118	15256297	44.18	30744388	0.59
Two incisions	42082416	12939589	30,75	41500008	

In the length measurements, we observed shortening of the patellar ligament and lowering of the patella in all of our cases (Figure 5 and Table 1).

Comparing the lengths of the patellar ligaments as seen during the operation and at the time of sacrifice, we concluded that there was significant shortening and increases in the circumference of the patellar ligament, for the same ligament. However, there was no difference between the two techniques (Figure 5).

**Figure 5** – Mean longitudinal length of the patellar ligament during the operation and at the time of sacrifice. Significant shortening of the ligament occurred similarly in both techniques

In the histological evaluation, we observed that the fibers lost their parallel orientation, collagen was interspersed, there were small numbers of blood vessels and the ligament had a chondroid appearance. However, there was no perceptible difference between the two techniques.

DISCUSSION

The discomfort of lesions of the infrapatellar branch of the saphenous nerve, which occurs in many patients who undergo harvesting of a graft from the patellar ligament by means of the traditional technique, justifies the attempts to find an alternative technique. The possibility of improvements in the scar esthetics and fewer vascular lesions are other points that motivated us to develop and study a new and less invasive technique.

Some techniques of a less invasive nature for harvesting grafts from the patellar ligament have been published in the literature^(1,2,3,9), and these have shown good results in relation to their objectives.

The technique of a single horizontal lesion, as described by Portland *et al*⁽¹⁰⁾, has the aim of avoiding injury to the infrapatellar branch of the saphenous nerve. However, this is a single long incision that is relatively aggressive, with the need for extensive detachment of subcutaneous tissue and stretching of the skin in order to achieve graft harvesting.

Kartus *et al*⁽¹⁾, Carneiro *et al*⁽²⁾, Tsuda *et al*⁽³⁾ and Garofalo *et al*⁽¹¹⁾ demonstrated the way in which less invasive techniques for graft harvesting, with two mini-incisions, could result in benefits for patients. They showed encouraging results.

However, these techniques raise doubts regarding the possibility that the remainder of the ligament might become weakened. Because of viewing difficulties, surgeons might harvest grafts that are excessively robust or, on the other hand, very thin, thereby affecting the mechanical properties of the remaining ligament.

Rupture of the patellar ligament following graft harvesting is a rare complication but it has been reported in the literature⁽¹²⁾. The fact that we were proposing a new technique without a precise harvesting control, along with the lack of suturing around the tendon, was a matter of concern for us and motivated us to conduct this study.

Thus, the present study is pertinent, given that in investigating in PubMed, we did not find any articles analyzing the repercussions on the resistance of the remaining patellar ligament, from the use of a less invasive technique. Even so, since this is a little used technique, the lack of reports on occurrences of complications does not constitute proof that there is no excessive weakening associated with this technique for graft harvesting.

In our clinical cases, we observed that harvesting the graft from the patellar ligament by means of two mini-incisions was easier to perform from distal to proximal, because at the insertion of the patellar ligament in the tibia, delimitation and viewing are both easier. The middle third of the ligament can be isolated using a blunt instrument of Kelly hemostatic type, or a Smillie knife for menisci. In the beginning, it may even be somewhat difficult to perform the technique, but after a few cases, it becomes easy and safe.

The non-closure of the superficial fascia in the minimally invasive technique was another factor that was of concern to us in relation to regeneration of the patellar ligament. However, we observed that there was no difference in tissue regeneration, either from a mechanical or from a histological point of view, thus showing that apparently, suturing the superficial fascia does not influence the repair process on the flaw that was created in the ligament.

Increases in the circumference of the patellar ligament were observed in both groups (Table 1). This may have been due to the shortening of the patellar ligament, but there was no doubt that it was not associated with the technique used for harvesting the graft.

Esthetic factors have also been of concern in ACL reconstruction⁽¹³⁾. From observing the scares from the two surgical techniques that we performed, it was clear that the two-incision technique was much more esthetically pleasing than the traditional technique. This was

probably because in the two-incision technique, the incisions were parallel to the skin crease lines, thus making them less evident and more esthetic.

Muellner *et al*⁽¹⁴⁾ reported lowering of the patella in 30% of their cases. In our study, the shortening of the patellar ligament was very significant (Table 1) and occurred in all cases. The reason for the shortening is a matter for debate, but it was undoubtedly not due to resting during the postoperative period, given that the animals were not restrained and were walking around soon after the surgery.

From a mechanical point of view, we observed that the rupture in the ligament tests occurred in the proximal third in most cases, and next to the patella. This occurred similarly in the two groups. In a study on patients who underwent revision of the ACL, Busfield *et al*⁽¹⁵⁾ reported one case of rupture next to the patella when a graft was harvested from the contralateral patellar ligament. This may suggest that the weakest point after harvesting the graft from the patellar ligament is the proximal insertion in the patella, and this is in line with our observations.

CONCLUSION

There was no significant difference in patellar ligament resistance between the two techniques analyzed. We did not observe any histological differences in the regeneration of the patellar ligament between the two techniques analyzed.

REFERENCES

1. Kartus J, Ejerhed L, Sernert N, Brandsson S, Karlsson J. Comparison of traditional and subcutaneous patellar tendon harvest. A prospective study of donor site-related problems after anterior cruciate ligament reconstruction using different graft harvesting techniques. *Am J Sports Med.* 2000;28(3):328-35.
2. Carneiro Filho M, Navarro RD, Cortelazo MJ. Reconstrução artroscópica do ligamento cruzado anterior com tendão patelar utilizando dupla incisão anterior transversa. *Rev Bras Ortop.* 1997;32(4):279-82.
3. Tsuda E, Okamura Y, Ishibashi Y, Otsuka H, Toh S. Techniques for reducing anterior knee symptoms after anterior cruciate ligament reconstruction using a bone-patellar tendon-bone autograft. *Am J Sports Med.* 2001;29(4):450-6.
4. Adam F, Pape D, Kohn D, Seil R. Length of the patellar tendon after anterior cruciate ligament reconstruction with patellar tendon autograft: a prospective clinical study using Roentgen stereometric analysis. *Arthroscopy.* 2002;18(8):859-64.
5. Krosser BI, Bonamo JJ, Sherman OH. Patellar tendon length after anterior cruciate ligament reconstruction. A prospective study. *Am J Knee Surg.* 1996;9(4):158-60.
6. Lee GH, McCulloch P, Cole BJ, Bush-Joseph CA, Bach BR Jr. The incidence of acute patellar tendon harvest complications for anterior cruciate ligament reconstruction. *Arthroscopy.* 2008;24(2):162-6.
7. Picado CHF, Paccola CAJ. Efeitos do enfraquecimento e da desvitalização do ligamento patelar de ovinos sobre sua resistência à tração. *Rev Bras Ortop.* 1996;31(9):759-70.
8. Rogers GJ, Millthorpe BK, Muratore A, Schindhelm K. Measurement of the mechanical properties of the ovine anterior cruciate ligament bone-ligament-bone complex: a basis for prosthetic evaluation. *Biomaterials.* 1990;11(2):89-96.
9. Drain O, Beaufils P, Thevenin LC, Boggione C, Katabi M, Charrois O et al. [Mini-invasive double-incision for patellar tendon harvesting in anterior cruciate ligament reconstruction]. *Rev Chir Orthop Reparatrice Appar Mot.* 2007;93(8):836-41.
10. Portland GH, Martin D, Keene G, Menz T. Injury to the infrapatellar branch of the saphenous nerve in anterior cruciate ligament reconstruction: comparison of horizontal versus vertical harvest site incisions. *Arthroscopy.* 2005;21(3):281-5.
11. Garofalo R, Mouhsine E, Chambat P, Siegrist O. Anatomic anterior cruciate ligament reconstruction: the two-incision technique. *Knee Surg Sports Traumatol Arthrosc.* 2006;14(6):510-6.
12. Marumoto JM, Mitsunaga MM, Richardson AB, Medoff RJ, Mayfield GW. Late patellar tendon ruptures after removal of the central third for anterior cruciate ligament reconstruction. A report of two cases. *Am J Sports Med.* 1996;24(5):698-701.
13. Levy HJ, Byck DC. Patellar tendon autograft harvesting using a mini vertical incision. *Arthroscopy.* 2000;16(5):558-62.
14. Muellner T, Kaltenbrunner W, Nikolic A, Mittlboeck M, Schabus R, Vecsei V. Shortening of the patellar tendon after anterior cruciate ligament reconstruction. *Arthroscopy.* 1998;14(6):592-6.
15. Busfield BT, Safran MR, Cannon WD. Extensor mechanism disruption after contralateral middle third patellar tendon harvest for anterior cruciate ligament revision reconstruction. *Arthroscopy.* 2005;21(10):1268.