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Healing of the patellar tendon after harvesting of its mid-third for anterior cruciate ligament reconstruction and evolution of the unclosed donor site defect

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Abstract. The purpose of this study was (a) to evaluate by ultrasonography the healing of the patellar tendon after its mid-third was removed for anterior cruciate ligament (ACL) reconstruction in two randomized groups of patients in whom the tendon donor site was either left open or closed; (b) to compare clinical, radiographic, and isokinetic studies of these two groups to evaluate the incidence of patellofemoral disorders. We performed 61 ACL reconstructions (22 males, 39 females) using the arthroscopically assisted in-out technique. All operations were performed by the same surgeon, and the patients were all subjected to the same postoperative protocol. The tendon defect was left open in 25 subjects (group A) and was closed in 36 subjects (group B). Postoperative patellar tendon behavior was evaluated in these two groups by ultrasonography at 3, 6, 9, and 12 months. The vertical position of the patella was measured in the follow-up lateral view at 45° of flexion and compared to that of the untreated knee. A clinical evaluation was performed throughout the follow-up period, and patellofemoral problems (pain, stiffness, patellofemoral crepitus) were evaluated and recorded using a modified Larsen and Lauridsen rating scale. Isokinetic evaluation was carried out at 6 months, and a quadriceps index of the two groups was recorded. Ultrasonography showed that healing of the patellar tendon initially progressed with a compensatory hypertrophy in width and thickness. The width was greater in group B ($P < 0.01$). In group A we observed in the cross-sections a characteristic image of two cords separated by a low signal bridge which we defined as a "binocular pattern." Areas of high ultrasound signal intensities persisted after 1 year in the open group; such areas were filled with scar tissue. In the closed group the ultrasound tendon signal returned to normal at 1 year. At 6 months the clinical, radiographic and isokinetic findings did not significantly differ between the open and closed groups. We conclude that defect closure after patellar tendon harvesting does not significantly influence the extensor apparatus.

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Key words: Patellar tendon – Ultrasonography – Anterior cruciate ligament – Quadriceps strength – Donor site

Introduction

In repairing an anterior cruciate ligament (ACL) deficient knee the central one-third of the patellar tendon is commonly harvested as a graft [8–11, 18, 25, 48]. This graft is used because of its strength and bone-to-bone fixation [34–36]. However, the literature reports several associated patellofemoral problems. Patellar fractures [5, 19, 33], patellar tendon rupture [19, 21, 28, 44], medial or lateral subluxation of the patella [26], and patella entrapment syndrome [39] have all been observed, although these are limited to case reports. More commonly, minor disorders, such as pain, patellofemoral crepitus, and patellar irritability symptoms, have been described for the patellofemoral joint [1, 2, 11, 24, 37, 42]. Repair of the patellar tendon defect has been thought to alter patellofemoral pressure and with adverse effects on the extensor mechanism [14, 17, 42]. Consequently it has been suggested that the defect be left open after harvest.

The purpose of this prospective study was to evaluate (a) intrinsic healing of the patellar tendon and (b) the incidence of patellofemoral complaints after harvest of the mid-third of the PT in patients with or without side-to-side repair of the tendon defect.

Materials and methods

From May 1992 to December 1992, 61 patients (61 knees) were operated only by the same surgeon (P.P.M.) for chronic isolated ACL tear, with a free graft from the mid-third of the patellar tendon. The average age of the 21 females and 40 males was 26 years (range 17–52). The right knee was involved in 33 subjects and the left knee in 28. The following exclusion criteria were established: (a) previous surgery of the injured knee, (b) significant injury to the controlateral knee, (c) the presence of additional surgical pro-

cedures, such as meniscus repair or surgery, on the same knee, and (d) lateral or medial laxity.

All patients underwent arthroscopically assisted ACL reconstruction with the in-out technique followed by the same rehabilitation program. Immediate passive range of motion was allowed postoperatively without restriction, but active terminal extension was delayed for 4 weeks; weight bearing was permitted as soon as was comfortable. During surgery the patients were randomly separated into two groups: in 25 patients a side-to-side repair of the patellar tendon defect was performed, and in 36 patients the defect was left open and only the peritenon was closed. The study procedure included the following tests for the two groups: ultrasound evaluation of the patellar tendon at 3, 6, 9, and 12 months, (b) radiographic examination of the knee at 6 months, (c) clinical evaluation of patellofemoral problems at 6 months, and (d), isokinetic testing at 6 months.

For each patient the ultrasound findings were compared to those of the other healthy knee. We used a Toshiba SSA 250 with a 7.5-MHz linear transducer. During each examination we determined the morphology and ecogenicity of the tendon in longitudinal and transverse scans and measured its relative size (thickness and width). The measurements were made bilaterally and symmetrically on the tendons of both knees (1 cm above the anterior tibial tuberosity and 1 cm from the lower pole of the patella) by the same examiner. To provide more regular and reproducible date, the results were analyzed by averaging the percentages of the size increment which affects the injured tendons with respect to the healthy side.

At the follow-up examination, the vertical position of the patella was measured in lateral view with the knee at 45° flexion and compared to that of the untreated knee. We used the Insall and Salvati method [22], taking a change in the index of greater than 5% as a significant lowering or lengthening of the patella. At clinical evaluation performed at 6 months, patellofemoral disorders were evaluated specifically using a modified Larsen and Lauridsen [29] rating scale. Pain, stiffness, and patellofemoral crepitus were noted and scored. The scores were divided into four categories (excellent, good, fair, poor); scores between 12 and 9 (excellent or good) were considered satisfactory and those less than 9 (fair or poor) as unsatisfactory. Scoring on the rating scale was as follows:

- Pain: 4 = none; 3 = occasional, minimal; 2 = after moderate activities; 1 = persistent
- Stiffness: 4 = none; 3 = occasional, minimal; 2 = after moderate activities; 1 = persistent
- Patellar crepitus: 4 = none; 3 = only with passive movements; 2 = after moderate activities; 1 = persistent
- Result: 11–12 = excellent; 9–10 = good; 7–8 = fair; less than 7 = poor.

Isokinetic evaluation was carried out using a GENU PLUS isokinetic testing device (DOC srl). The peak quadriceps torque at 100°/s 240°/s was measured and compared with that of the contralateral normal side. The ratio of the peak torque obtained in the operated and healthy knees yields the quadriceps index [31]. We report the quadriceps index of the two groups as percentage values.

Statistical analysis of results was performed with the chi-square test, adopting a level of significance of $P < 0.05$.

Results

Ultrasound studies

Ultrasound examination showed the width of the patellar tendon to be increased in both groups, although it was

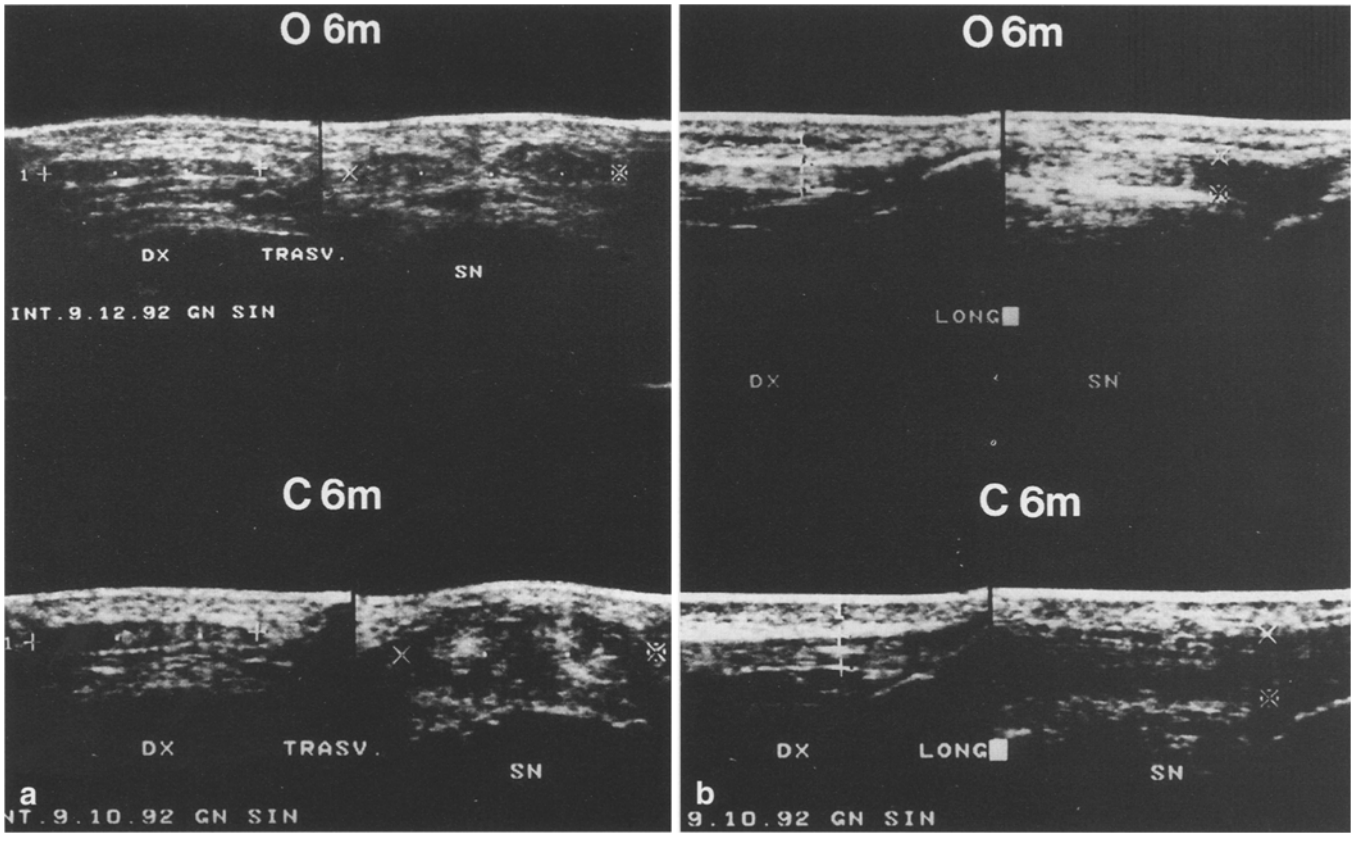

Fig. 1 a, b. Ultrasound evaluation at 6-month follow-up: transverse (**a**) and longitudinal (**b**) scans. Comparison of the patellar tendon with the contralateral healthy knee. Note the characteristic ultrasonographic picture that we term "binocular." *SN*, Operated side; *O*, open tendon; *C*, closed tendon

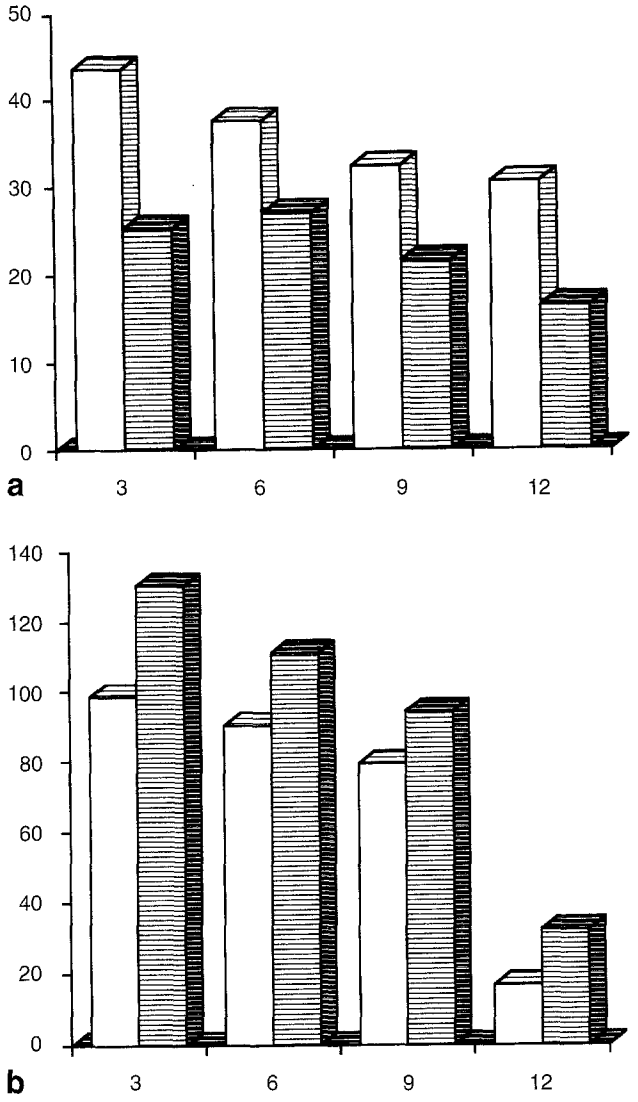

Fig. 2a, b. Modifications of tendon width (**a**) and tendon thickness (**b**) in the two groups, expressed as percentage change from the controlateral healthy side. □, Open; ■, closed

proportionally greater ($P < 0.01$) in the open group (Fig. 1 a). At 3 months the operated tendon was 43.59% wider than that of the healthy knee in the open group and 25.21% wider in the closed group; at 6 months 37.54% wider in the open group and 26.91% in the closed group; at 9 months tendon width was similar to previous values (32.33% in the open and 21.56% in the closed); and at 1 year the operated tendon was still wider in both groups (30.5% in the open and 16.47% in the closed techniques; Fig. 2 a).

The thickness of the patellar tendon also increased in the two groups (Fig. 1 b). The percentage increase (Fig. 2 b) was greater in the group whose tendon was sutured closed, although analysis did not show significant statistical differences. At 3 months the tendon increased in thickness by 98.59% in the open group and 130.26% in the closed group; at 6 months this increase fell to 90.15% in the unclosed tendons and 111.11% in the closed tendons; at 9 months the values decreased (79.38% in the open and 94.21% in the closed); at 1 year tendon thickening was markedly reduced in both the open (16.66%) and closed (32.23%) tendons.

Table 1. Results of the clinical evaluation (percentages; differences nonsignificant)

	Open	Closed
Positive	86	76
Excellent	44	32
Good	42	44
Negative	14	24
Fair	11	20
Poor	3	4

In both groups the ecogenicity of the tendon diminished in the first few months due to postoperative edema; the peritendinous structures (sheath and peritenon) seem to fold inwards at the site of the excised graft, producing a characteristic ultrasonographic picture that we termed "binocular", appearing as two cords separated by a hyperecogenous bridge (Fig. 1). In cross-section the two cords had an ecogenic core surrounded by a hyperecogenous ring. This aspect was more clearly evident in the tendons where only the peritenon was sutured, especially at the 3-months examination.

In the first few months the unsutured tendons displayed a clear separation between the lateral cords with the formation of two parallel semitendons, which decreased in size over time. At the 1 year follow-up the cords were still distinct, but new tissue filled the central area; this tissue did not yet display the ultrasonographic features of true tendon structure, and we termed it "regenerated tendon". Real-time ultrasonographic analysis of the two cords during muscle contraction showed homogeneous and symmetrical behavior. At 1 year the ecogenicity of the closed tendon returned to normal. The patellar bone defect was still evident at 1 year even if we observed a slow bone regenerating process arising from the bottom of the defect. In only one case of group B was a tendon calcification close to the patellar apex detected.

Clinical evaluation

The rating scale indicated better overall results in patients in whom the tendon was not sutured. The mean subjective scores were 9.88 in the open tendon group and 9.36 in the closed group, but statistical significance was not achieved. The mean scores of the individual parameters basically overlapped in the two groups. The outcomes were classified into four groups (excellent, good, fair, poor). The open group had a slightly higher rating, which, however, was not statistically significant. Positive outcomes (excellent or good) were found in 86.12% of the open group and 76% of the closed group (Table 1).

Radiographic evaluation

The follow-up radiographs confirmed the persistence of the patellar notch at the graft site, and only one subject had tendon calcifications, as already identified by ultrasonography. In only a minority of subjects in both groups did the Insall and Salvati index of patellar height differ

significantly between the operated and contralateral knees. Indeed, only two cases of patellar lowering (one in each group) were observed, and one case of patellar lengthening was found in the open group.

Isokinetic tests

Isokinetic testing performed an average of 6 months after the operation revealed no significant differences between the two groups. At low velocity (100°/s) we found a quadriceps index of 74.15 in the open group and 72.06 in the closed group. At high speed (240°/s) the quadriceps index was 79.33 in the open group and 79.78 in the closed group.

Discussion

Our work evaluated two problems in the use of central patellar tendon grafts for ACL repair. On the one hand, with ultrasonography we followed the course of the closed or open tendon defect after harvesting of its central third; on the other, we evaluated the effects on the extensor mechanism of repairing or not repairing the patellar tendon defect. Our ultrasound findings support the results in the literature [3, 4, 12, 15, 16 30, 33] of appreciable compensatory hypertrophy of the tendon remnant, with an increase in tendon width and especially thickness in the postoperative period. In agreement with Dupont et al. [16], we found that tendon hypertrophy peaks at 6 months and tends to decrease over time.

Ultrasonographic evaluation of the first stages of the healing process indicated a greater central growth inwards of the peritendinous structures in nonsutured tendons, which decreased with time. In agreement with the findings of Rosenberg et al. [41], at the 12- and 24-month follow-ups we found in cross-sections that the tendon defect persisted in "open" tendons. At 12 months this defect seemed to fill with tendinouslike scar tissue strongly adhering to the remnant tendon. Tendon regeneration has previously been demonstrated [13, 40, 45, 49]. Using histological studies and magnetic resonance imaging, in one case Berg [3] found that the tendon defect was filled by tissue which in time assumed the characteristics of the normal tendon. In magnetic resonance imaging study Meisterling et al. [33] reported no significant morphological differences between the normal and donor patellar tendons an average of 2.5 years after bone-tendon-bone ACL reconstruction. Recently Karns et al. [23] repaired the knee of a professional athlete using the central third of the patellar tendon that had been harvested 4 years before; their histological studies confirmed both complete regeneration of the tendon and filling-in of the patellar and tibial bony defect.

Our ultrasonographic studies of the donor site showed persistence of the bony defect of the tibial and patellar surface after 1 year. We believe that this finding, confirmed radiographically, is due in part to bone necrosis at the cut surface caused by the circular saw and in part to folding inwards of the overlying soft tissues into the bony defect, which interferes with filling-in of the bone defect. To avoid this complication, which leads to esthetic problems and may predispose to stress fractures, we have begun filling the patellar defect with bone grafted from the tibia.

The major criticism of the use of the mid-third of the homologous patellar tendon for ACL reconstruction stems from the consideration that removing one-third of a structure crucial to the extensor apparatus of the knee must in some way have negative repercussions.

Patellofemoral problems are the most frequent complication after ACL repair using the patellar tendon. In a series of 50 patients Clancy et al. [11] found a 35% incidence of patellofemoral pain. In a review of 87 patients with follow-up after 8 years Johnson et al. [24] reported a 12% incidence of negative outcomes due to the persistence of patellofemoral pain. In a prospective study and 11-year literature review Sachs et al. [42] gave an incidence of patellofemoral pain in 12%–32% of subjects with patellar tendon grafts having a higher incidence than hamstring grafts. O'Brien et al. [37] reported a 28% incidence of patellofemoral pain, and Aglietti et al. [1, 2] identified patellofemoral problems in 21.5% of a series of arthroscopic ACL reconstructions using free patellar tendon grafts. However, patellofemoral problems have also been reported after ACL reconstruction with the hamstring tendon [38, 46], with allografts [43], and after conservative treatment of ACL tear [35]. Thus, the factor underlying the incidence of extensor mechanism problems is probably more closely related to rehabilitation protocol and surgical technique rather than the choice of the graft harvest site. Moreover, it has been hypothesized that leaving the tendon defect open might reduce the incidence of patellofemoral problems [3, 6, 8, 50, 51].

However, we did not find statistically significant different rates of patellofemoral problems in the open and closed groups. The incidence of negative outcomes on our rating scales (fair or poor) was 13.88% in the open group and 24% in the closed group. Only one subject in each group presented severe patellofemoral problems, such as persistent pain or stiffness, of a degree sufficient to compromise the clinical outcome.

It has also been hypothesized that closure of the patellar defect may modify the height of the patella. Hardin et al. [21] reported lowering of the patella, with a 9% average loss of patellar height. Tria et al. [51] found lowering of the patella in 76% of 29 subjects with ligament reconstruction, and they concluded that closure of the tendon defect was responsible for this result, although the radiographic modifications did not appear correlated with either clinical outcome or patellofemoral pain.

In experiments in dogs, Burks et al. [6] found that the operated patellar tendon shortened by approximately 10% compared to the controlateral knee. This contrasts with the results of Meisterling et al. [33], who found no subjects with a lowered patella after bone-tendon-bone ACL reconstruction in a revision of 15 cases. Shaffer et al. [47] found no evidence that the use of patellar tendon autograft leads to significantly measurable patella tendon shortening, and that closure of the defect does not appreciably contribute to patellar tendon shortening.

Our radiographic studies also failed to demonstrate a significant lowering of the patella in either group. We believe that patella infera is not related to the harvest of the patellar tendon but to other factors, such as inflammatory

events and the presence of a significant reflex inhibition with quadriceps weakness [7]. Indeed, in our study, isokinetic testing demonstrated that closure of the tendon defect did not appreciably affect quadriceps strength. Recovery of muscle strength in the quadriceps was similar in the two groups and in line with the results on other authors employing different surgical techniques [20].

In conclusion, in agreement with the literature, our ultrasound, clinical, radiographic, and isokinetic results show that the tendon defect after harvesting for ACL repair can be either sutured or left open without having a significant influence on the extensor apparatus.

In dogs Burks et al. [6] demonstrated a resultant increased cross-sectional area and relative shortening of the operated tendon, irrespective of whether the central one-third defect was closed or left open. Similarly, Eilerman et al. [17] in their work with fresh-frozen human knees found no differences in patellar contact pressure with or without repair of the tendinous gap. D'Agata et al. [14] in an in vitro study reported that neither harvesting the central 10 mm of the patellar tendon nor closing the gap significantly altered patellofemoral contact area or pressure. Shaffer et al. [47] found no patellar tendon shortening, with or without closure, and they recommend leaving the choice of technique to the individual surgeon.

Sachs et al. [42] concluded that the most common problems of the extensor apparatus after ACL repair, contraction in flexion, patellofemoral pain, and quadriceps weakness, are intimately related, and they hypothesed a chain of interlinked events, having in common contraction in flexion, which accordingly must be given priority of treatment. In agreement with this approach, we believe that the following are of fundamental importance in limiting problems with the extensor apparatus of the knee after surgical reconstruction: (a) correct surgical technique with correct positioning of the graft and (b) prompt rehabilitation that aimed at the rapid recovery of full knee extension, involving immediate mobilization of the knee joint and suitable physiotherapy, such as continuous passive motion, quadriceps electrotherapy, and passive mobilisation of patella.

Conclusions

1. Patellar tendon healing initially progresses with compensatory hypertrophy evident both in width and thickness. Areas with high ultrasound signal intensities are still present after 1 year in the open group, and this area is filled with scar tissue.
2. Radiographic, clinical, and isokinetic evaluation did not detect significant differences between the open and closed technique.

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