Physeal Sparing Reconstruction of the Anterior Cruciate Ligament in Skeletally Immature Prepubescent Children and Adolescents

Surgical Technique

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INTRODUCTION

Intrasubstance injuries of the anterior cruciate ligament in children and adolescents are being seen with increased frequency and have received increased attention[1-10]. There is controversy regarding the management of anterior cruciate ligament injuries in patients with open physes. Nonoperative management of complete tears generally has a poor outcome, with instability leading to further meniscal and chondral injury[11-17]. Conventional surgical reconstruction techniques are associated with a risk of iatrogenic growth disturbance due to damage to the distal femoral physis and/or the proximal tibial physis from graft channels that cross these open growth plates[18-23]. In this article, we describe a physeal sparing, combined intra-articular and extra-articular reconstruction with use of an autogenous iliotibial band graft in skeletally immature prepubescent children and adolescents.

SURGICAL TECHNIQUE

This procedure is a modification of the combined intra-articular and extra-articular reconstruction

ABSTRACT

BACKGROUND:

The management of anterior cruciate ligament injuries in skeletally immature patients is controversial. Conventional adult reconstruction techniques risk potential iatrogenic growth disturbance due to physeal damage. The purpose of this study was to evaluate the results of a physeal sparing, combined intra-articular and extra-articular reconstruction technique in prepubescent skeletally immature children.

METHODS:

Between 1980 and 2002, forty-four skeletally immature prepubescent children and adolescents who were in Tanner stage 1 or 2 (with a mean chronological age of 10.3 years) underwent physeal sparing, combined intra-articular and extra-articular reconstruction of the anterior cruciate ligament with use of an autogenous iliotibial band graft. Twenty-seven patients had additional meniscal surgery. Functional outcome, graft survival, radiographic outcome, and growth disturbance were evaluated at a mean of 5.3 years after surgery.

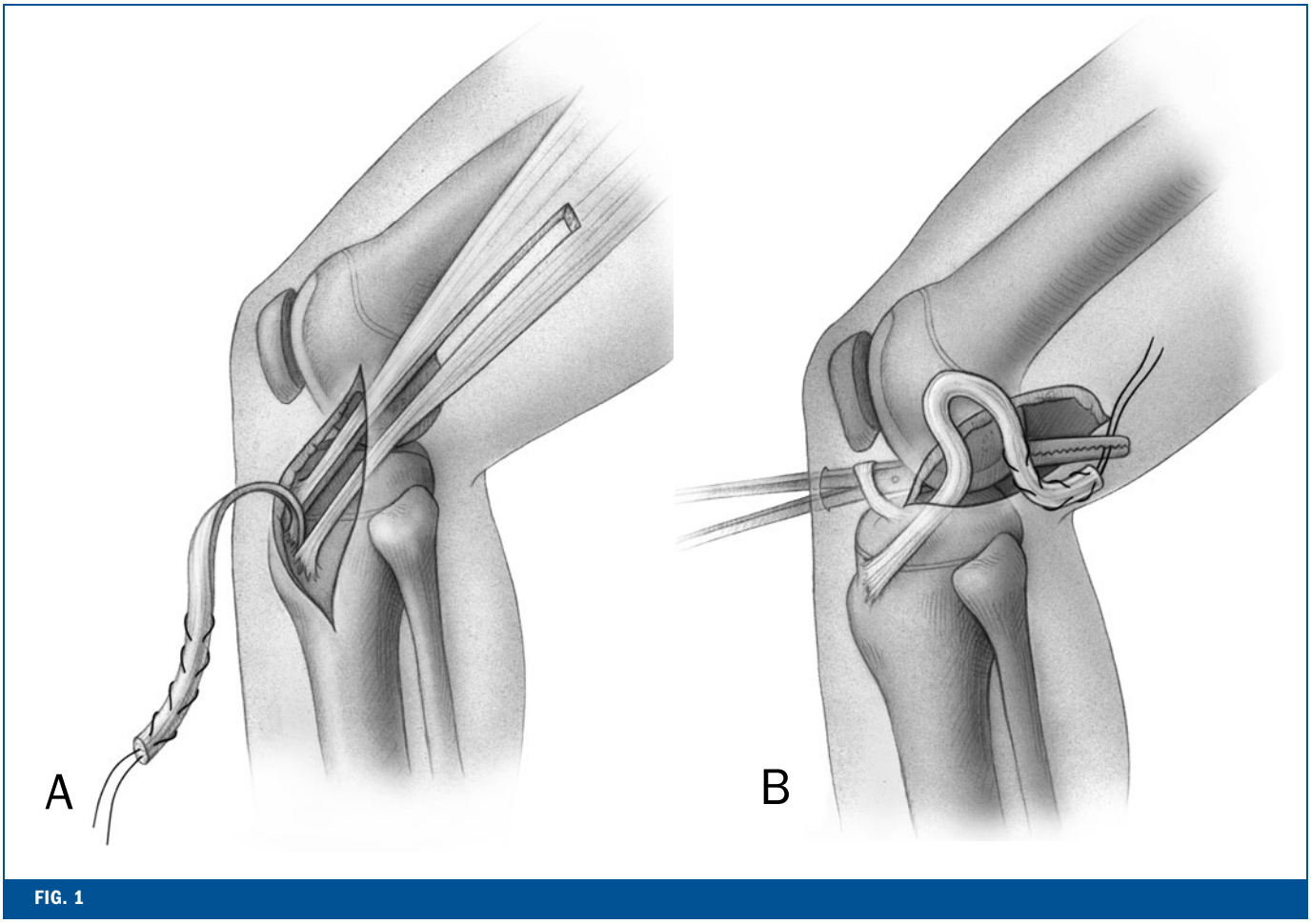

FIG. 1

described by MacIntosh and Darby[24]. Modifications include application in skeletally immature patients, arthroscopic assistance, graft fixation, and accelerated rehabilitation[25].

The operation is performed with the patient under general anesthesia and as an overnight-

ABSTRACT | continued

RESULTS:

Two patients underwent a revision reconstruction for graft failure at 4.7 and 8.3 years postoperatively. In the remaining forty-two patients, the mean International Knee Documentation subjective knee score (and standard deviation) was 96.7 ± 6.0 points, and the mean Lysholm knee score was 95.7 ± 6.7 points. The results of the Lachman examination for anterior cruciate ligament integrity were normal for twenty-three patients, nearly normal for eighteen patients, and abnormal for one patient. The results of the pivot-shift examination were normal for thirty-one patients and nearly normal for eleven patients. Four of the twenty-three patients who underwent concurrent meniscal repair had a repeat arthroscopic meniscal repair or partial meniscectomy. The mean growth in total height from the time of surgery to the final follow-up evaluation was 21.5 cm. No patient had an angular deformity measured radiographically or a discrepancy in the length of the lower extremities measured clinically.

CONCLUSIONS:

Physeal sparing, combined intra-articular and extra-articular reconstruction of the anterior cruciate ligament with use of an autogenous iliotibial band graft in skeletally immature prepubescent children and adolescents provides excellent functional outcome with a low revision rate and a minimal risk of growth disturbance.

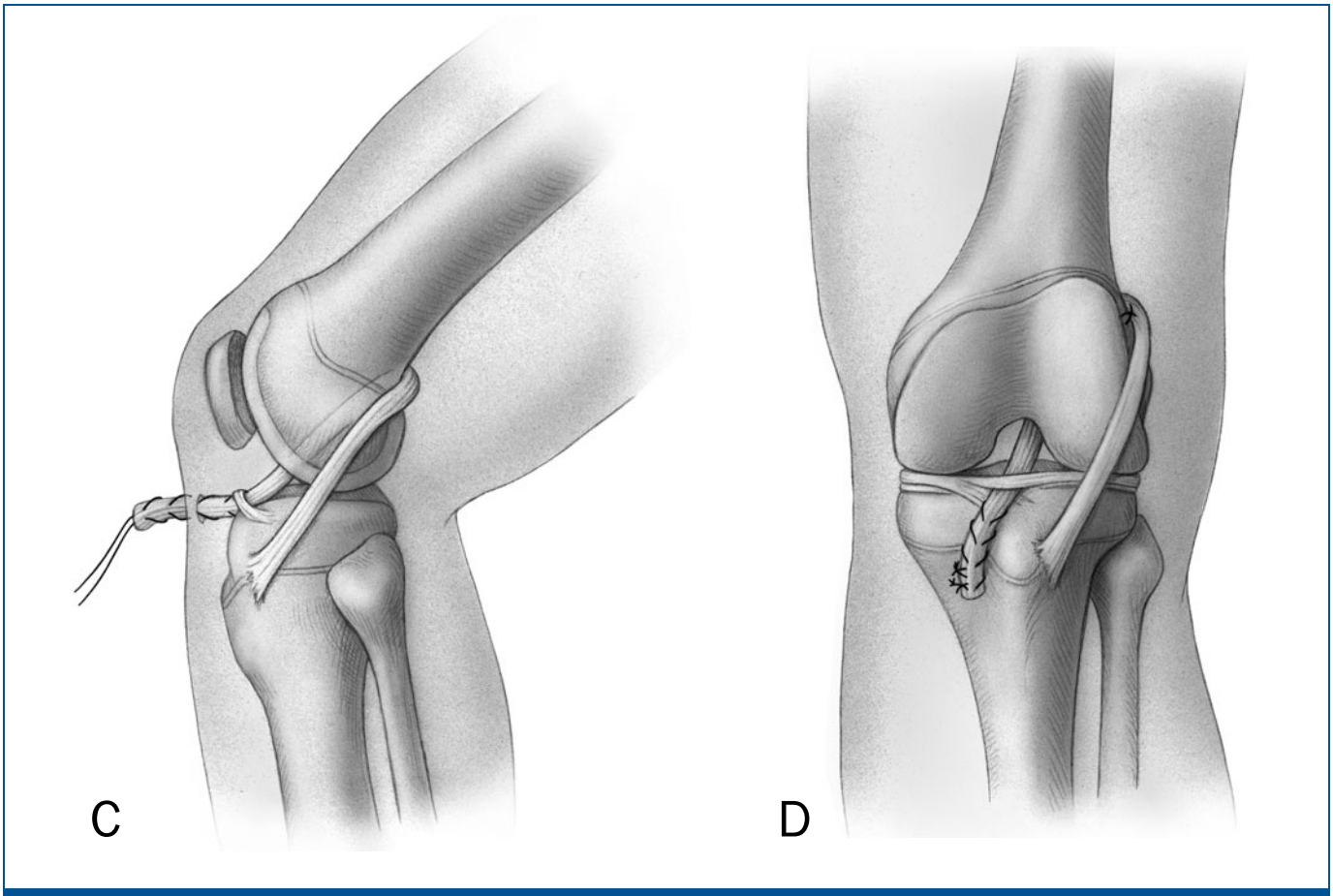

FIG. 1 (CONTINUED)

Physeal sparing, combined intra-articular and extra-articular reconstruction with use of an autogenous iliotibial band for prepubescent patients. *A:* The iliotibial band graft is harvested free proximally and left attached to Gerdy's tubercle distally. *B:* The graft is brought through the knee in the over-the-top position posteriorly. *C:* The graft is brought through the knee and under the intermeniscal ligament anteriorly. *D:* The graft is fixed to the intermuscular septum on the femoral side and to the periosteum of the proximal part of the tibia on the tibial side.

observation procedure. The child is positioned supine on the operating table, and a pneumatic tourniquet about the proximal part of the thigh is used routinely. Examination with the patient under anesthesia is performed to confirm insufficiency of the anterior cruciate ligament. The leg is exsanguinated with an Esmarch bandage and the tourniquet inflated. The knee joint is preinjected with local anesthetic.

An incision of approximately 6 cm is made obliquely from the lateral joint line to the superior border of the iliotibial band. Proximally, the iliotibial band is separated from the subcutaneous tissue with use of a periosteal elevator under the skin of the lateral aspect of the thigh. The anterior and posterior borders of the iliotibial band are incised, and the incisions are carried proximally under the skin with use of curved meniscotomes (Figs. 1, *A*, and 2).

The iliotibial band is detached proximally under the skin with use of a curved meniscotome or an open tendon stripper, and it is left attached distally at Gerdy's tubercle (Fig. 1, *A*). Dissection is performed distally to separate the iliotibial band from the joint capsule and from the lateral patellar retinaculum (Fig. 3). The free proximal end of the iliotibial band is then tubularized with use of a whip stitch with number-5 Ethibond suture (Ethicon, Johnson and Johnson, Somerville, New Jersey) (Fig. 1, *A*).

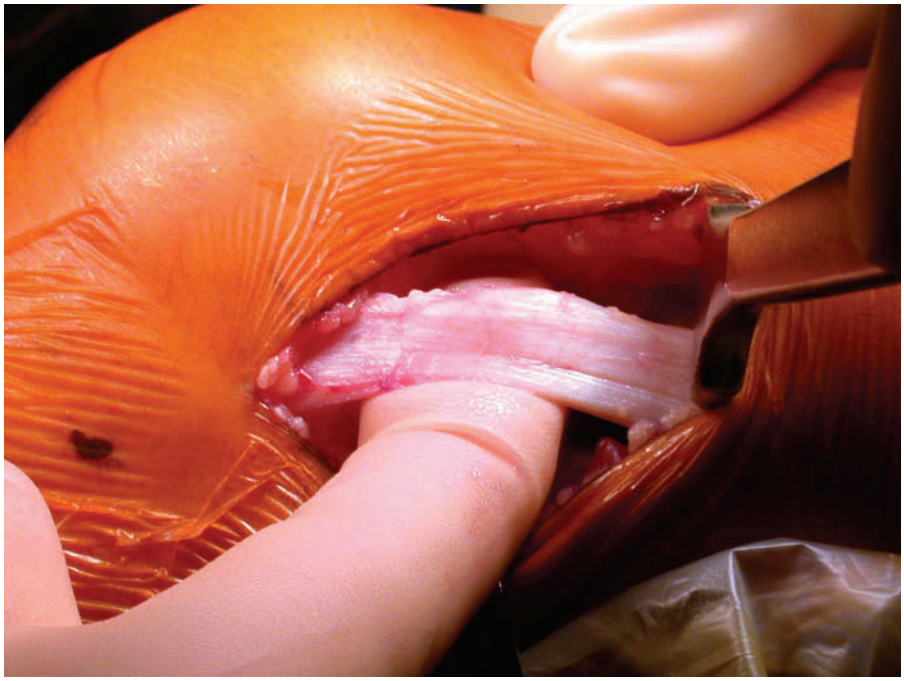

FIG. 2

The iliotibial band is harvested through an oblique lateral knee incision.

FIG. 3

The iliotibial band graft is detached proximally, left attached distally, and dissected free from the lateral patellar retinaculum.

Arthroscopy of the knee is then performed through standard anterolateral and anteromedial portals. Meniscal injury or chondral injury is managed as indicated. The remnant of the anterior cruciate ligament is excised. The over-the-top position on the femur and the over-the-front position under the intermeniscal ligament are identified. A minimal notchplasty is performed to avoid iatrogenic injury to the perichondrial ring of the distal femoral physis, which is in close proximity to the over-the-top position (Fig. 4)[26,27]. The free end of the iliotibial band graft is then brought through the over-the-top position with use of a full-length clamp (Fig. 5) or a two-incision rear-entry guide (Fig. 1, *B*) from an extra-articular to an intra-articular location and out through the anteromedial portal (Figs. 6 and 7).

A second incision of approximately 4.5 cm is made over the proximal-medial aspect of the tibia in the region of the pes anserinus. Dissection is carried through the subcutaneous tissue to the periosteum. A curved clamp is placed from this inci-

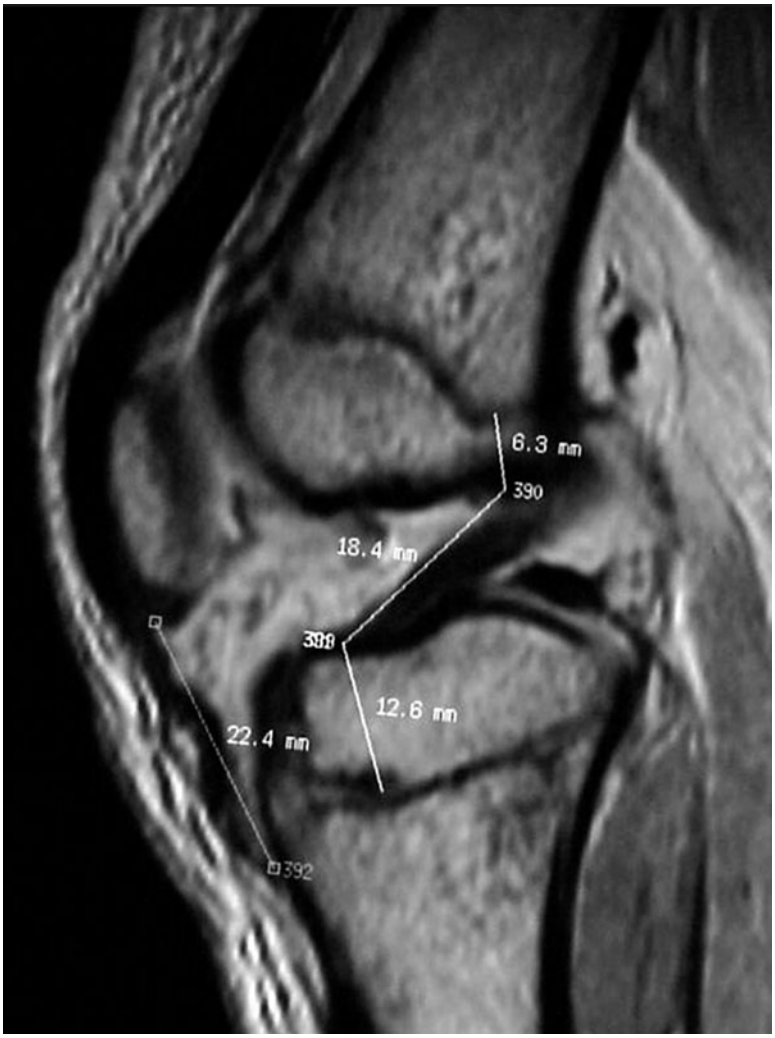

FIG. 4

A sagittal magnetic resonance imaging scan demonstrating the proximity of the femoral origin of the anterior cruciate ligament to the posterior edge of the distal femoral physis (only 6.3 mm here).

CRITICAL CONCEPTS

INDICATIONS:

A complete midsubstance tear of the anterior cruciate ligament in a prepubescent child (Tanner stage 1 or 2) for whom nonoperative treatment consisting of rehabilitation, bracing, and activity restriction has failed (Fig. 13). These patients have symptoms related to knee pivoting or further meniscal or chondral injury related to instability.

CONTRAINDICATIONS:

- Pubescent adolescents (Tanner stage 3). Such patients should be treated with transphyseal reconstruction with autogenous hamstring tendons and fixation away from the growth plate (Fig. 13).
- Proximal tears of the anterior cruciate ligament, which are amenable to primary repair, and distal tibial spine fractures, which are treated with arthroscopic reduction and internal fixation.
- A child who will not cooperate with postoperative rehabilitation.

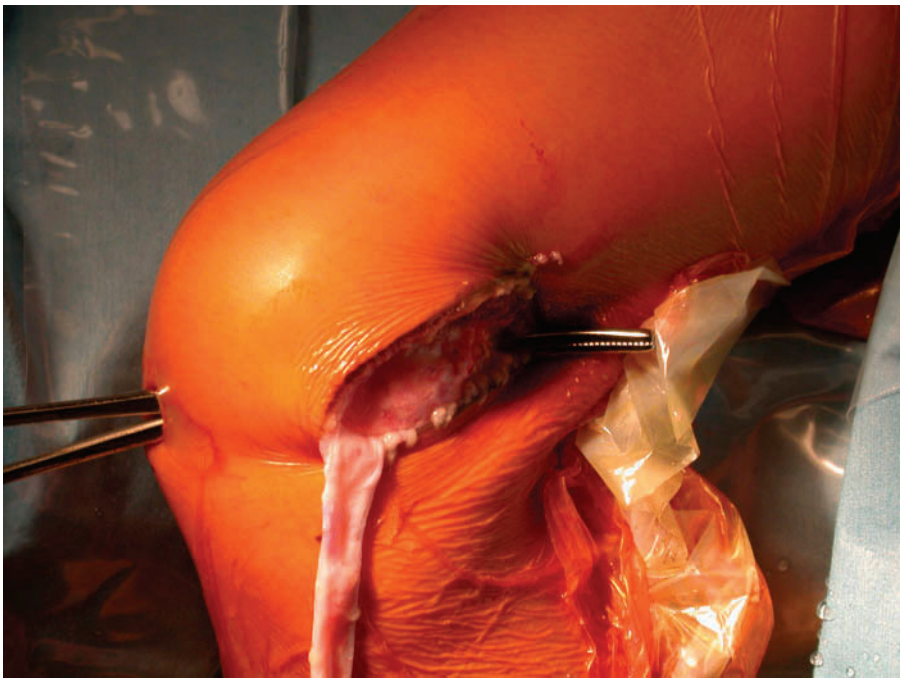

FIG. 5

The iliotibial band graft is brought through the knee with use of a full-length clamp placed from the anteromedial portal through the over-the-top position into the lateral incision.

sion into the joint under the intermeniscal ligament (Fig. 8). A small groove is made in the anteromedial aspect of the proximal tibial epiphysis under the intermeniscal ligament with use of a curved rat-tail rasp to allow the graft to lie more posteriorly (Fig. 9). The free end of the graft is brought through the knee under the intermeniscal ligament (Fig. 10) and out through the proximal-medial tibial incision (Fig. 11).

The graft is fixed on the femoral side through the lateral incision, with the knee in 90° of flexion and 15° of external rotation (Fig. 12), with use of mattress sutures to the lateral femoral condyle at the insertion of the lateral intermuscular sep-

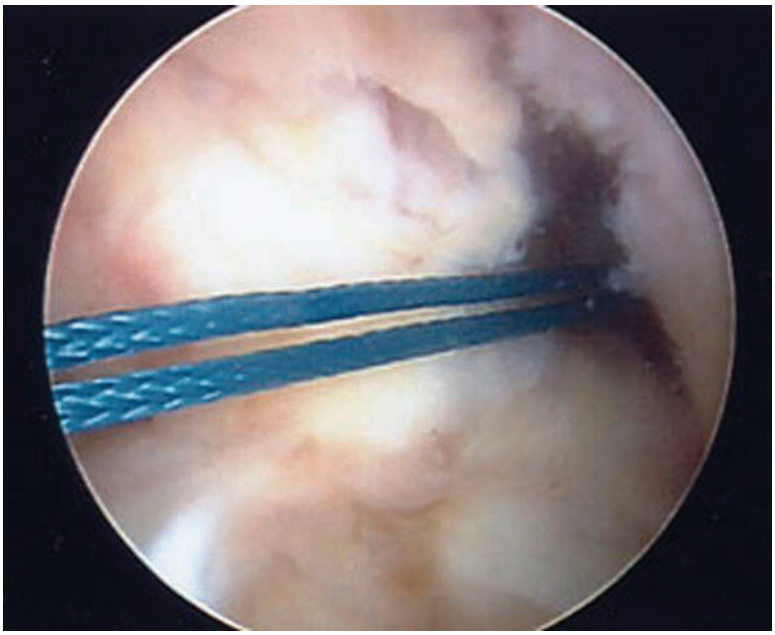

FIG. 6

The sutures of the graft are brought through the over-the-top position.

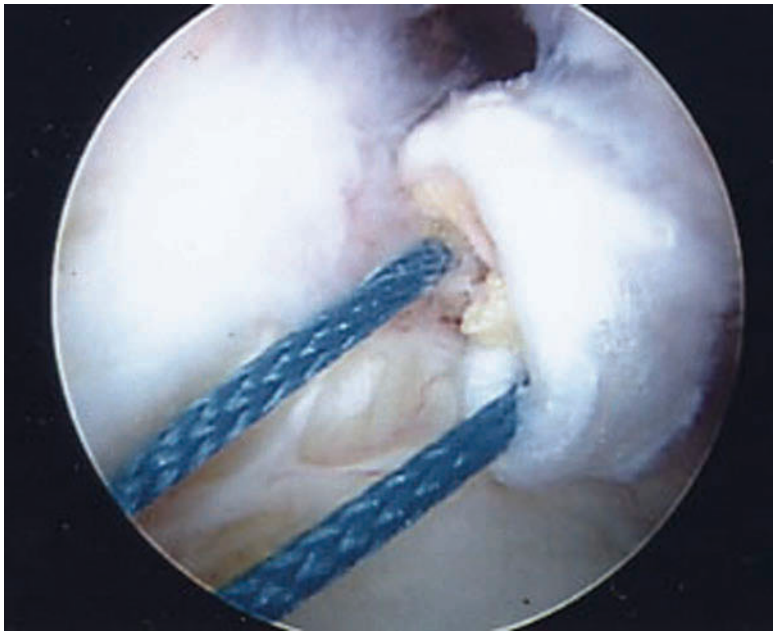

FIG. 7

The graft is brought through the over-the-top position.

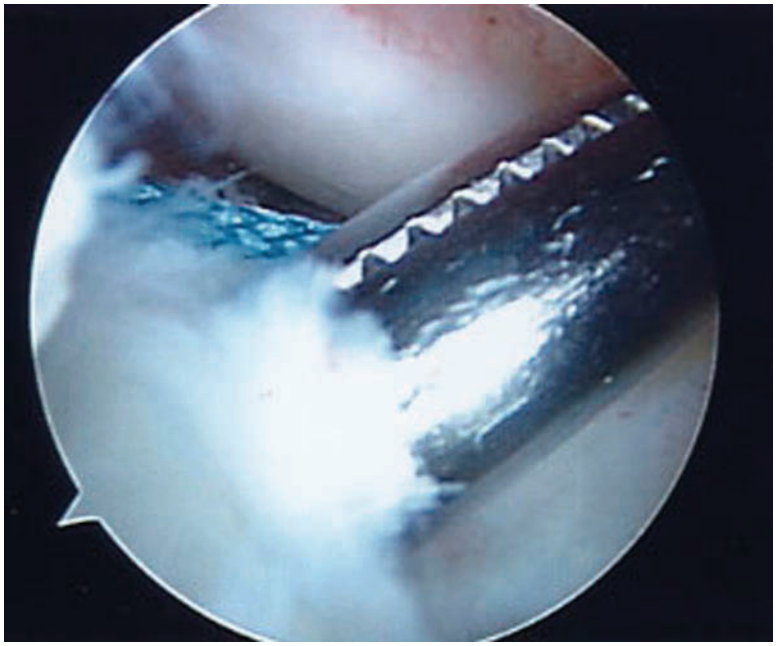

FIG. 8

A clamp is placed from a proximal-medial tibial incision under the intermeniscal ligament.

CRITICAL CONCEPTS | continued

PITFALLS:

- Failure to adequately assess the stage of growth and development of the patient. In addition to chronological age, skeletal age should be determined from a hand and wrist radiograph and the Tanner stage should be determined by the physician or the patient on the basis of a chart.
- Harvesting an iliotibial band graft of insufficient length. This can be avoided by using a sufficiently long incision, using a tendon stripper, or making a counter incision proximally in the thigh.
- Detachment of the iliotibial band from Gerdy's tubercle. When the graft is dissected distally, care should be taken to not transect it just proximal to Gerdy's tubercle.
- Vigorous notchplasty or over-the-top-position dissection. This can result in physeal injury since the perichondrial ring is in close proximity (Fig. 4).
- Failure to bring the graft under the intermeniscal ligament or chamfering of a groove in the proximal tibial epiphysis under the intermeniscal ligament, which can result in a more anterior and horizontal graft placement then desired.
- Inadequate tibial fixation. Suture fixation to a trough within the periosteum is usually sufficient; however, this can be supplemented with a staple or a screw and post.
- Prolonged cast immobilization, which can lead to stiffness postoperatively.

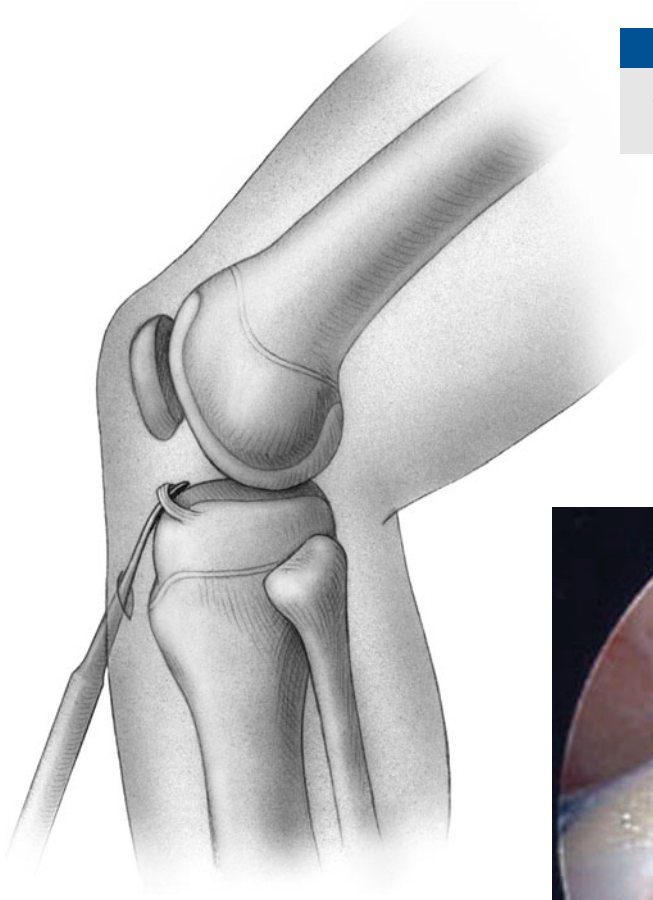

FIG. 9

A curved rasp is used to make a groove in the proximal tibial epiphysis under the intermeniscal ligament.

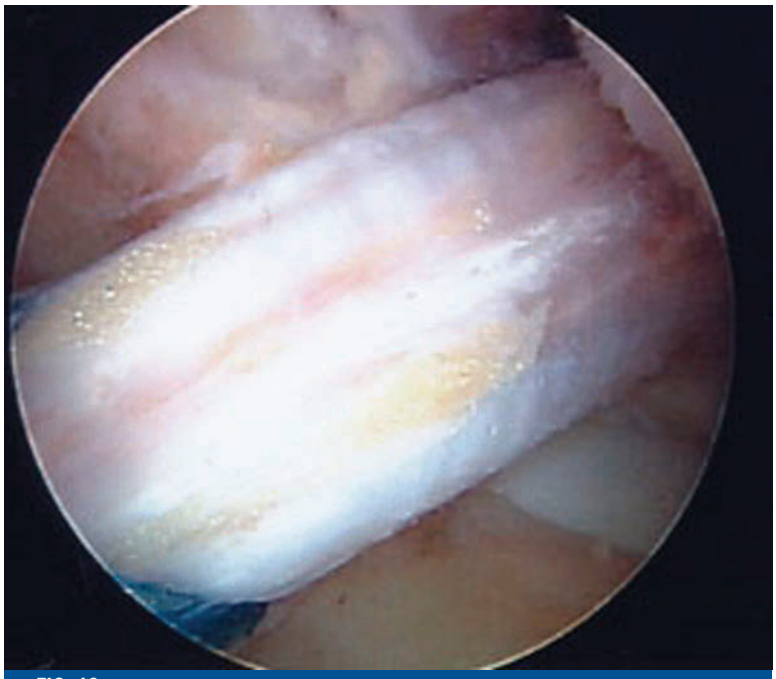

FIG. 10

The graft is brought through the knee in the over-the-top position and under the intermeniscal ligament.

tum to effect an extra-articular reconstruction (Fig. 1, *D*). The tibial side is then fixed through the medial incision with the knee flexed 20° and with tension applied to the graft. A periosteal incision is made distal to the proximal tibial physis and is confirmed with fluoroscopic imaging. A trough is made in the proximal tibial medial metaphyseal cortex, and the graft is sutured to the periosteum at the rough margins of the trough with mattress sutures (Fig. 1, *D*).

Immediate mobilization of the limb is performed, from 0° to 90° for the first two weeks, followed by progression to a full range of motion. Continuous passive motion from 0° to 90° is used for the first two weeks postoperatively to initiate motion and to overcome the anxiety associated with postoperative movement that is experienced by these children. The patient walks

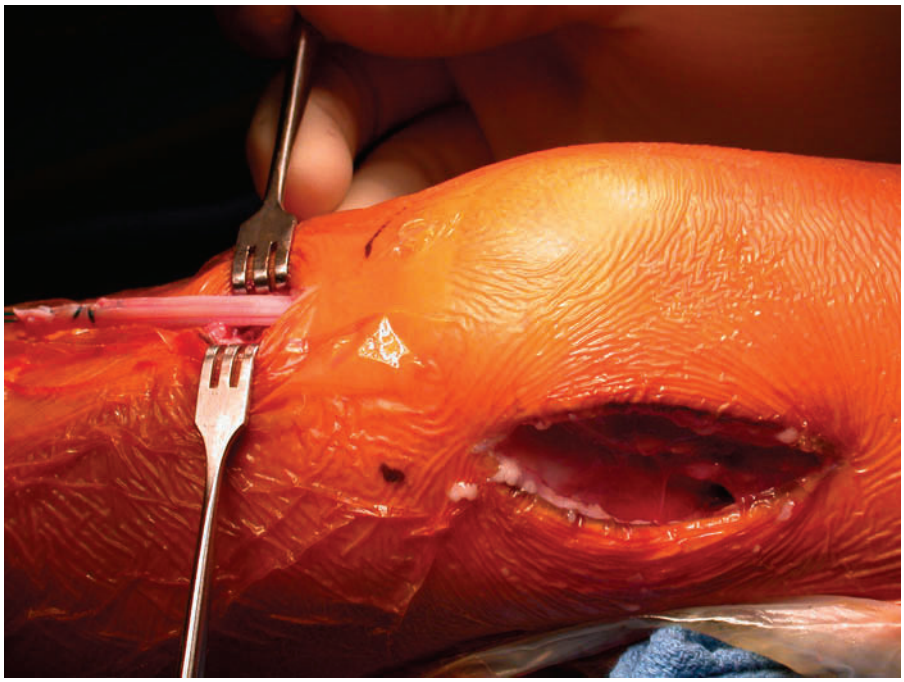

FIG. 11

The graft is brought out through the proximal-medial tibial incision.

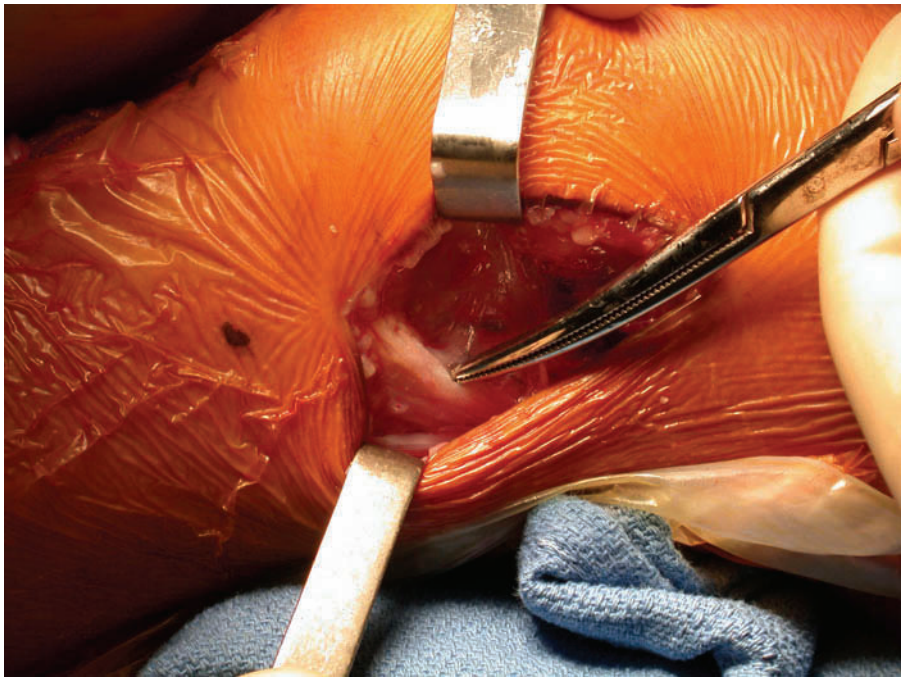

FIG. 12

On the femoral side, the graft is sutured to the intermuscular septum and the periosteum of the lateral femoral condyle.

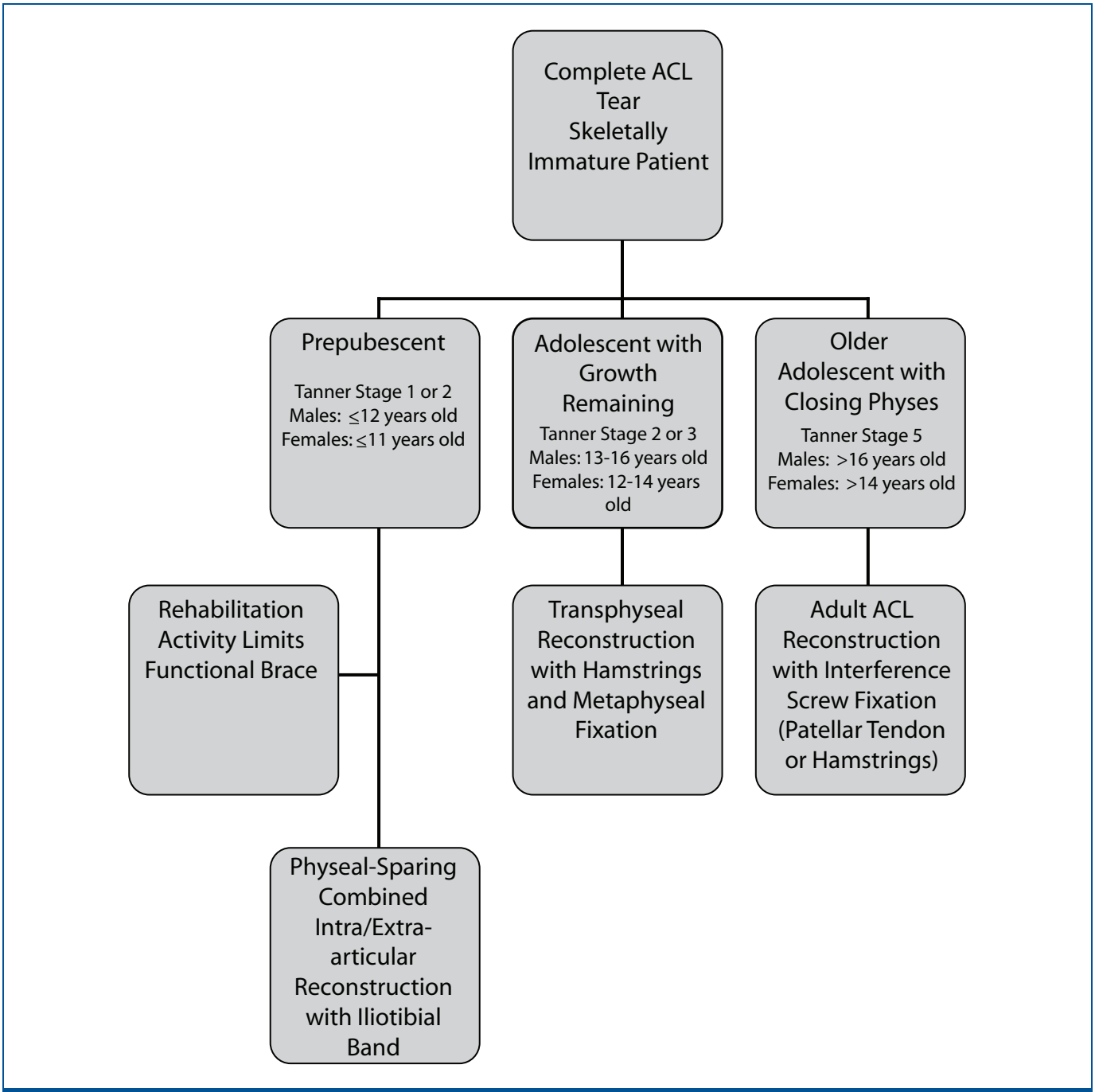

FIG. 13

Treatment algorithm for the management of anterior cruciate ligament injuries in skeletally immature patients.

with crutches and toe-touch weight-bearing for six weeks. A protective hinged knee-brace is also used for six weeks, with motion limits of 0° to 90° for the first two weeks. Progressive rehabilitation consists of range-of motion exercises, patellar mobilization, electrical stimulation, pool therapy if available, proprioception exercises, and closed-chain strengthening during the first three months postoperatively. This is followed by straight-line jogging, sport cord exercises, and sport-specific exercises. Return to full activity, including cutting sports, is usually

CRITICAL CONCEPTS | continued

AUTHOR UPDATE:

The technique has not changed since publication of the original article.

allowed at six months. A custom functional knee-brace is used routinely during cutting and pivoting activities for the first two years after the return to sports.

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REFERENCES

1. Kocher MS, Micheli LJ, Gerbino P, Hresko MT. Tibial eminence fractures in children: prevalence of meniscal entrapment. Am J Sports Med. 2003;31:404-7.

2. Rang M. Children's fractures. 2nd ed. Philadelphia: JB Lippincott; 1983.

3. Kocher MS, Foreman ES, Micheli LJ. Laxity and functional outcome after arthroscopic reduction and internal fixation of displaced tibial spine fractures in children. Arthroscopy. 2003;19:1085-90.

4. Kocher MS, Mandiga R, Klingele K, Bley L, Micheli LJ. Anterior cruciate ligament injury versus tibial spine fracture in the skeletally immature knee: a comparison of skeletal maturation and notch width index. J Pediatr Orthop. 2004;24:185-8.

5. Eiskjaer S, Larsen ST, Schmidt MB. The significance of hemarthrosis of the knee in children. Arch Orthop Trauma Surg. 1988;107:96-8.

6. Kloeppel-Wirth S, Koltai JL, Dittmer H. Significance of arthroscopy in children with knee joint injuries. Eur J Pediatr Surg. 1992;2:169-72.

7. Kocher MS, DiCanzio J, Zurakowski D, Micheli LJ. Diagnostic performance of clinical examination and selective magnetic resonance imaging in the evaluation of intra-articular knee disorders in children and adolescents. Am J Sports Med. 2001;29:292-6.

8. Luhmann SJ. Acute traumatic knee effusions in children and adolescents. J Pediatr Orthop. 2003;23:199-202.

9. Stanitski CL, Harvell JC, Fu F. Observations on acute knee hemarthrosis in children and adolescents. J Pediatr Orthop. 1993;13:506-10.

10. Vahasarja V, Kinnuen P, Serlo W. Arthroscopy of the acute traumatic knee in children. Prospective study of 138 cases. Acta Orthop Scand. 1993;64:580-2.

11. Aichroth PM, Patel DV, Zorrilla P. The natural history and treatment of rupture of the anterior cruciate ligament in children and adolescents. A prospective review. J Bone Joint Surg Br. 2002;84:38-41.

12. Graf BK, Lange RH, Fujisaki CK, Landry GL, Saluja RK. Anterior cruciate ligament tears in skeletally immature patients: meniscal pathology at presentation and after attempted conservative treatment. Arthroscopy. 1992;8:229-33.

13. Janarv PM, Nystrom A, Werner S, Hirsch G. Anterior cruciate ligament injuries in skeletally immature patients. J Pediatr Orthop. 1996;16:673-7.

14. McCarroll JR, Rettig AC, Shelbourne KD. Anterior cruciate ligament injuries in the young athlete with open physes. Am J Sports Med. 1988;16:44-7.

15. Millett PJ, Willis AA, Warren RF. Associated injuries in pediatric and adolescent anterior cruciate ligament tears: does a delay in treatment increase the risk of meniscal tear? Arthroscopy. 2002;18:955-9.

16. Mizuta H, Kubota K, Shiraishi M, Otsuka Y, Nagamoto N, Takagi K. The conservative treatment of complete tears of the anterior cruciate ligament in skeletally immature patients. J Bone Joint Surg Br. 1995;77:890-4.

17. Pressman AE, Letts RM, Jarvis JG. Anterior cruciate ligament tears in children: an analysis of operative versus nonoperative treatment. J Pediatr Orthop. 1997;17:505-11.

18. Guzzanti V, Falciglia F, Gigante A, Fabbriciani C. The effect of intra-articular ACL reconstruction on the growth plates of rabbits. J Bone Joint Surg Br. 1994;76:960-3.

19. Edwards TB, Greene CC, Baratta RV, Zieske A, Willis RB. The effect of placing a tensioned graft across open growth plates. A gross and histologic analysis. J Bone Joint Surg Am. 2001;83:725-34.

20. Houle JB, Letts M, Yang J. Effects of a tensioned tendon graft in a bone tunnel across the rabbit physis. Clin Orthop Relat Res. 2001;391:275-81.

21. Lipscomb AB, Anderson AF. Tears of the anterior cruciate ligament in adolescents. J Bone Joint Surg Am. 1986;68:19-28.

22. Koman JD, Sanders JO. Valgus deformity after reconstruction of the anterior cruciate ligament in a skeletally immature patient. A case report. J Bone Joint Surg Am. 1999;81:711-5.

23. Kocher MS, Saxon HS, Hovis WD, Hawkins RJ. Management and complications of anterior cruciate ligament injuries in skeletally immature patients: survey of the Herodicus Society and The ACL Study Group. J Pediatr Orthop. 2002;22:452-7.

24. MacIntosh DL, Darby TA. Lateral substitution reconstruction [abstract]. In: Proceedings and reports of universities, colleges, councils, and associations. J Bone Joint Surg Br. 1976;58:142.

25. Micheli LJ, Rask B, Gerberg L. Anterior cruciate ligament reconstruction in patients who are prepubescent. Clin Orthop Relat Res. 1999;364:40-7.

26. Behr CT, Potter HG, Paletta GA Jr. The relationship of the femoral origin of the anterior cruciate ligament and the distal femoral physeal plate in the skeletally immature knee. An anatomic study. Am J Sports Med. 2001;29:781-7.

27. Kocher MS, Hovis WD, Curtin MJ, Hawkins RJ. Anterior cruciate ligament reconstruction in skeletally immature knees: an anatomical study. Am J Orthop. 2005;34:285-90.