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Growth Arrest of the Tibia After Anterior Cruciate Ligament Reconstruction

Lengthening and Deformity Correction With the Taylor Spatial Frame

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Keywords: Taylor Spatial Frame; Ilizarov; growth arrest; anterior cruciate ligament (ACL) complication

Anterior cruciate ligament (ACL) injury in skeletally immature patients is associated with a poor prognosis related to meniscal and chondral injury.[1] In addition to the usual risks of surgery, growth arrest of open physes must also be considered when ACL reconstruction is performed for these patients. Although the initial treatment of a very skeletally immature patient with an acute ACL injury remains controversial,[3] surgery is indicated for recurrent instability.[10]

Standard bone tunnels and fixation methods using a soft tissue allograft or autograft are thought to be the most effective technique in the adult population because it provides the most accurate anatomical reconstruction of the ligament.[4,10] Adolescents who are near skeletal maturity and who have limited growth remaining are at a minimal risk of developing a deformity with standard bone tunnels and fixation methods, even if they sustain a partial physeal arrest. Performing transphyseal ACL reconstruction on children with wide open physes has a similar benefit, although it carries some increased risk of physeal growth plate damage.[10] Consequently, some surgeons attempt all-epiphyseal or over the top/over the front techniques to avoid drilling holes in the distal femoral and proximal tibial physes.[2,10]

This report documents a case of severe tibial deformity and shortening after transphyseal ACL reconstruction. Lengthening and correction of the deformity were accomplished with the Taylor Spatial Frame.

CASE REPORT

A 17-year-old male patient had an acquired leg-length discrepancy (LLD) and deformity after ACL reconstruction performed at age 12 after a ski injury. Reconstruction was performed using an Achilles allograft by an experienced surgeon. The graft was fixed in an anatomically placed tibial tunnel in which a plug was countersunk and tied over a button for secure fixation. The allograft was placed with the bone block in the tibia tied over a button. Based on the radiographs, it appeared that no metal was used on the tibial side of the knee.

No tunnel was drilled on the femoral side, and the graft was placed intra-articularly and over the top of the lateral femoral condyle. The Achilles allograft was then put on tension and fixed to the lateral femur using 2 small staples. There was no evidence of meniscal or chondral injury, and there was minimal postoperative swelling and pain. Over the course of several years, there progressively emerged a deformity of the right tibia associated with an LLD. The patient lived in England and there was little follow-up with the ACL surgeon. He was referred to our service and came from England for treatment at age 17, which was 4.5 years after initial ACL surgery. We describe this case and the correction using distraction osteogenesis in conjunction with a Taylor Spatial Frame (TSF) (Smith & Nephew Inc, Memphis, Tennessee) using the Ilizarov method.

Physical Examination

At presentation, 4.5 years after ACL reconstructive surgery, the patient was 17 years old; he was 5 feet, 7 inches

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Figure 1. A, preoperative clinical front view; B, preoperative 51-inch AP view; C, preoperative AP view of right knee; D, preoperative clinical side view; E, preoperative lateral view of right knee.

tall and weighed 131 lb. (The height of his father was 5 feet, 10 inches and that of his mother was 5 feet, 7 inches.) At that time his bone age was 15 years. Tanner stage examination was not performed. He had LLD with obliquity of the pelvis. He felt symmetrical with a 4-cm block under the short leg. This block height leveled the pelvis and was consistent with the LLD as measured on the radiograph.

He had a varus and extension deformity of his leg (Figure 1). His gait was steady with an asymmetrical foot

TABLE 1
Preoperative and Postoperative Radiographic Measurements[a]

Time	MAD (mm)	LLD (cm)	Δ Femur (cm)	Δ Tibia (cm)	LDFA (deg)	MPTA (deg)	PPTA (deg)
Preoperative	44 medial	4.5	0.6	3.4	84	72	112
Postoperative	7 medial	0	0.6	0.6[b]	82	81	92

[a]MAD, mechanical axis deviation (normal: 3-17 mm medial); LLD, leg-length discrepancy; LDFA, lateral distal femoral angle (normal: 85° to 90°); MPTA, medial proximal tibial angle (normal: 85° to 90°); PPTA, posterior proximal tibial angle (normal: 77° to 84°).[19]
[b]Right tibia overlengthened by 0.6 cm to compensate for femoral discrepancy.

Figure 2. Clinical front view (A) and clinical side view (B) immediately after application of the frame.

progression angle of approximately 15° externally rotated on the right side compared with the left. Thigh foot axis of the right side was 30° externally rotated and the left side was 15° externally rotated. He had approximately 15° of external rotational deformity. Knee motion on the right was 30° of apparent hyperextension to 130° of flexion without instability. Knee motion on the left was 10° of hyperextension to 130° of flexion. Lachman and pivot-shift tests were negative; other ligaments were also stable. Ankle and hip range of motion were within normal limits. He had normal motor and sensory function with normal pedal pulses bilaterally. Ankle plantar flexion and dorsiflexion were within normal range.

Radiographs

The radiographs were measured to analyze length and deformity using the malalignment test.[19,20] The mechanical axis deviation was measured. Joint orientation angles including lateral distal femoral angle, medial proximal tibial angle, and posterior proximal tibial angle were measured (Table 1). The deformity was defined as a varus recurvatum with an LLD of 4.5 cm. There were 15° of varus, 28° of apex posterior angulation, and 15° of external rotation. The tibia had a varus and apex posterior deformity stemming from growth arrest of the proximal tibial physis. The physis was closed anteriorly and medially. Because the patient had not yet reached skeletal maturity, further growth from the posterior and lateral part of the affected proximal tibia could have resulted in the development of additional deformity. Based on the multiplier method of Paley and Herzenberg,[18] there were approximately 8 to 10 mm of growth remaining from the contralateral lower extremity; the patient was predicted to have an LLD at maturity of approximately 5.5 cm.

Treatment

Gradual lengthening and correction of the deformity were performed using distraction osteogenesis with a TSF with the Ilizarov method. First, a complete epiphysiodesis of the right proximal tibia was performed to prevent any recurrence of deformity. Then an oblique osteotomy of the fibula was made. The frame was applied to match the deformity (Figure 2). A multiple drill hole transverse osteotomy of the tibia was performed and struts were applied, stabilizing the osteotomy in a nondisplaced position. The rate of correction planned was 1 mm per day, which began 7 days postoperatively. Weightbearing was encouraged throughout treatment. At the end of

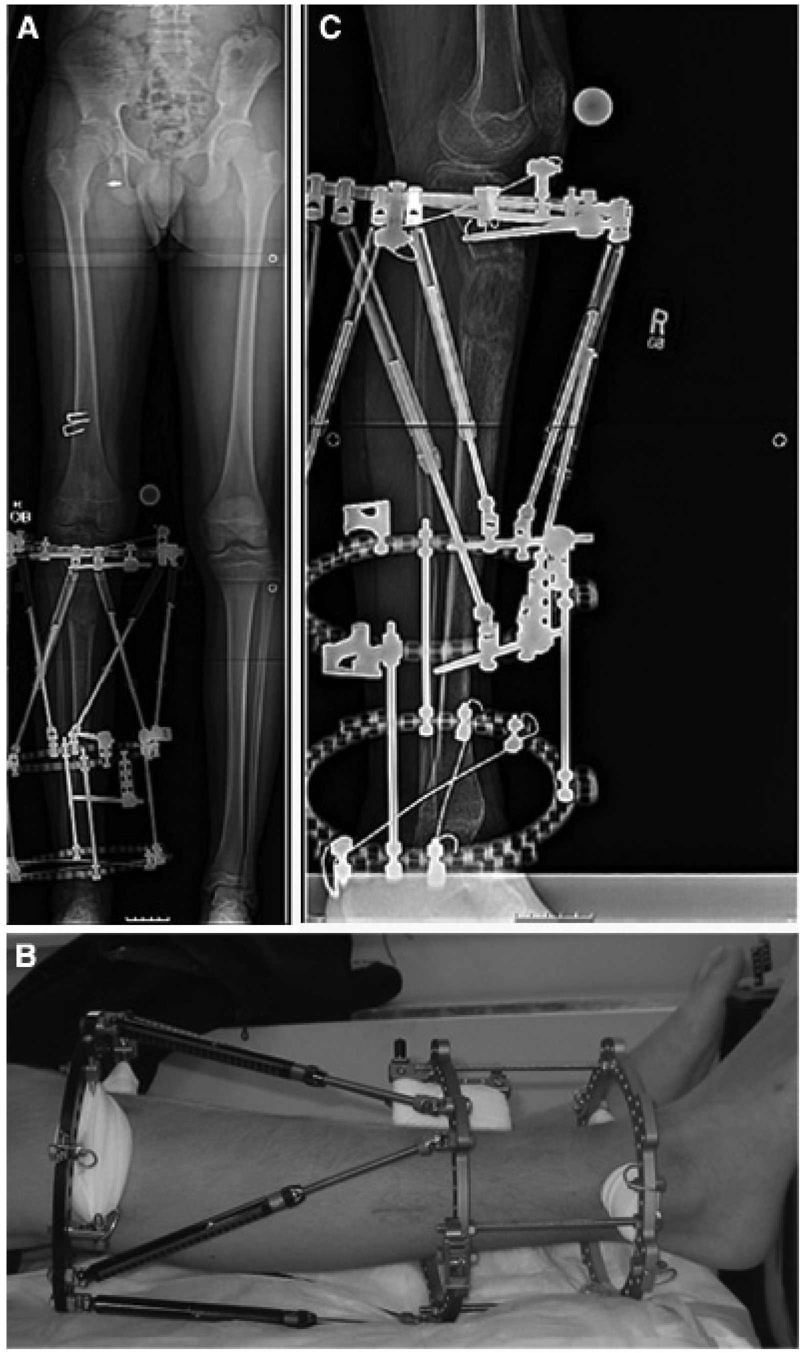

Figure 3. A 51-inch AP view (A), clinical side view (B), and lateral view (C) of the right tibia at end of distraction.

correction, the distraction gap measured 55 mm and the patient was ambulating with full weightbearing (Figure 3). Alignment and LLD were corrected (Table 1).

The frame was removed after 6 months. The patient was ambulating well after frame removal, although he reported some minimal discomfort. Clinically, he was without any deformity. Lachman and pivot-shift tests were negative. Range of motion of the knee and ankle were within normal limits. His latest follow-up examination was 1 year after the tibia and fibula osteotomy for lengthening and deformity correction. At age 18, he was skeletally mature with a height of 5 feet, 11 inches. He had no LLD or deformity (Table 1). He has resumed all sports activity, including competitive soccer, without limitation (Figure 4).

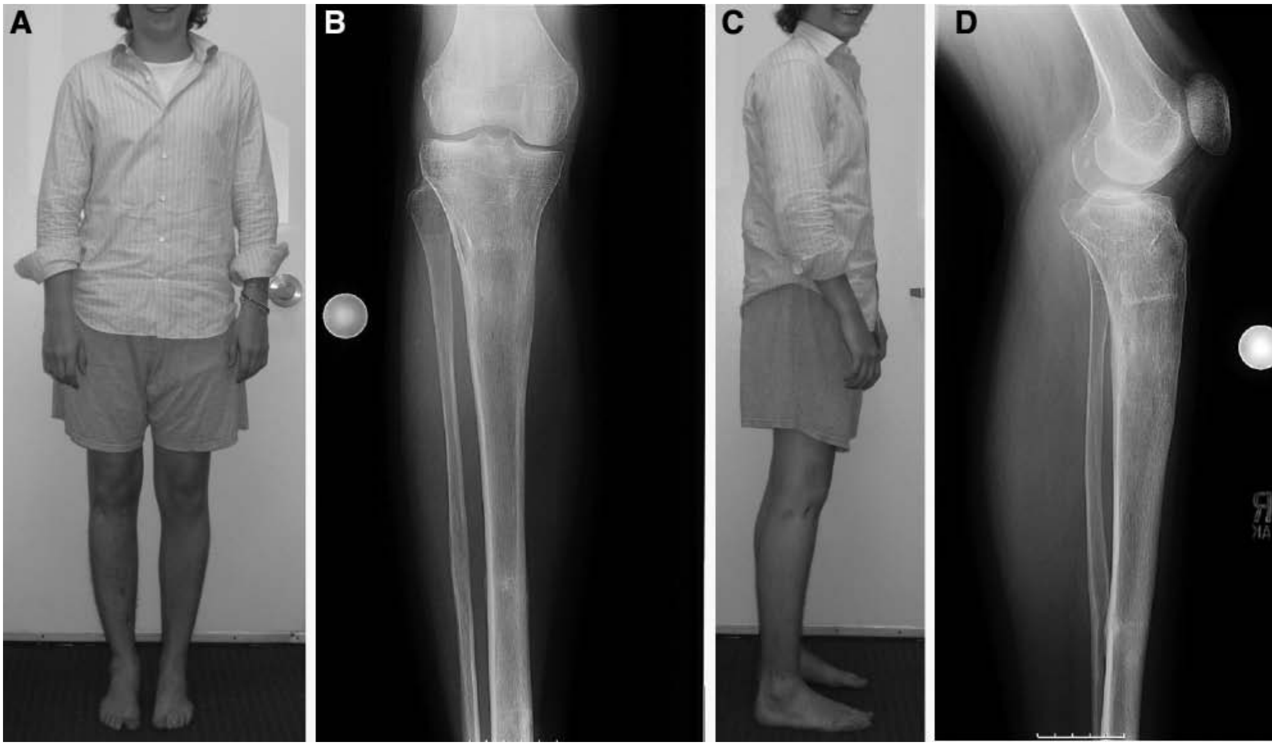

Figure 4. Clinical front view (A), AP view (B), clinical side view (C), and lateral view (D) of right tibia at end of treatment.

DISCUSSION

In recent years there has been an increase in the frequency of reported ACL tears among skeletally immature individuals.[§] Nonoperative treatment of such injuries is seldom effective, often leading to further knee joint complications.[6,13-15,20] Consequently, surgical intervention in which the ACL is reconstructed remains the best treatment option for patients with recurrent instability. Anatomical reconstruction of the ligament is optimal; however, skeletal immaturity of children and adolescents makes this technique run the risk of physeal growth plate damage.

Several studies indicate that the occurrence of physeal damage after ACL reconstruction using standard bone tunnels is rare, provided that an appropriate graft is chosen and an experienced surgeon performs the procedure.[2,4,5,11,13,14,21] Others propose that growth arrest is contingent upon the size of the drill holes,[7] the placement of the soft tissue graft[16] and hardware,[11] and graft tension.[24] Case studies report that there is evidence that growth arrest and deformity can occur as a complication of ACL reconstruction in skeletally immature patients.[12,16,23]

Malalignment as a result of deformity disturbs the normal transmission of force across the knee, which can result in degenerative arthropathy of the joint.[25] Application of a TSF with the Ilizarov method permits multiaxial correction of deformities to correct lower limb alignment and curtail future development of arthropathy.[20] In our case, we corrected a varus and recurvatum deformity, bringing the alignment of the right limb to within normal limits. The right limb was also slightly overlengthened so the total length of both legs was expected to be even when skeletal maturity was attained. At the latest follow-up the patient was without deformity. Clinically, leg lengths were equal and he could walk without assistance and without a limp. He was engaged in competitive soccer without any restrictions.

In our case, the tibial tunnel contributed to partial growth plate arrest. Consequently, normal growth of the proximal tibial physis was interrupted, resulting in the development of deformity and LLD. The tunnel and fixation did not appear to be in contact with the growth plates. It is not clear what caused physeal growth plate arrest. The growth arrest of the tibia could have resulted from the bone plug being placed across the physis or perhaps the heat generated during tunnel drilling could have injured the physis in such an immature child. It is possible that the patient had a rapid growth spurt that led to tension across the physis, caused by the graft, which in turn led to physeal closure. The maturing physes surrounding the knee are at risk for injury in developing adolescents. It has been reported that extreme hyperextension of the knee may also cause a compressive injury to the tibia and lead to growth arrest.[8]

Ideally, close follow-up should have been done every 6 months until the end of growth, but because the family lived in England, this was not convenient for them. Such follow-up could be helpful in diagnosing the growth arrest and enabling early and perhaps more simple intervention. However, in this case, epiphysiodesis of the opposite leg

[§]References 2, 6, 9, 10, 14, 15, 17, 21, 22, 24.

would not have been a satisfactory solution for 2 reasons. First, there was significant deformity of the operated leg that required correction. Second, the predicted LLD was 5.5 cm. An epiphysiodesis of the opposite leg would have resulted in significant loss of height.

In cases of acquired deformities that may develop as a result of reconstruction, our outcome indicates that correction of the deformity and LLD can be performed successfully with use of a TSF and the Ilizarov method.

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