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Incidence of Iatrogenic Physeal Bar Formation in a Paediatric Population Undergoing Transphyseal ACL Reconstruction Using A Validated High-Resolution MRI Protocol at 12 Months Post Surgery

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Summary:
In a skeletally immature population MRI imaging was used to evaluate effects of transphyseal ACL reconstruction on physeal bar formation.

Data:
Introduction Transphyseal paediatric anterior cruciate ligament (ACL) reconstruction presents a risk of angular limb deformity and limb length discrepancy in the growing child. The exact pathogenesis of these growth-related complications remains poorly understood. It is thought that physeal bar formation adjacent to ACL graft tunnels is one possible cause. Other causes include metabolic stimulation of growth plate and physeal tethering due to graft tension. Many previous studies on the effects of transphyseal ACL in paediatric populations review older children who are beyond skeletal maturity at time of surgery. This may underestimate the effect of transphyseal tunnel placement on the growing physeal.

In addition, a recently validated knee MRI bone age atlas improves our ability to distinguish between normal physiological physeal closure and iatrogenic growth plate injury. This study evaluates the incidence of iatrogenic physeal bar formation in a paediatric population undergoing transphyseal ACL reconstruction using a previously validated high-resolution MRI protocol. Methods A prospective series of paediatric patients undergoing transphyseal ACL reconstruction (using hamstring autograft with double suspensory fixation) at a single institute was conducted from 2015-2021. High resolution 3T MRIs were performed at 12 months post-surgery. A validated knee bone age MRI atlas was then used to exclude patients with evidence of physiological physeal closure indicative of skeletal maturity at the 12 month post-surgery follow up. Patients with partial physiologically physeal closure were included as long as greater than two-thirds of the physis was open and the area of closure was not within 1.5cm of the tunnels. The remaining skeletally immature MRI scans were appraised by two independent reviewers for the presence of physeal bar formation adjacent to transphyseal ACL tunnels. Results 114 patients met the inclusion criteria for age. Following bone age screening of 12 month post-surgery MRI scans, 73 patients were excluded as they exhibited evidence of complete physiological closure of either the tibial or femoral physis. Of the remaining 41 patients (31 male; 10 female), all had open fibular physis, 12 had partial closure of the tibial physis, and 5 had partial closure of both the tibial and femoral physis. Mean age at time of surgery was 14.2 years (9.8-16.7). Two cases of physeal bar formation were found in two males (ages at surgery 14.2 and 14.7) both of whom had otherwise completely open physis. No leg length discrepancy was observed for these two patients at 12 month long leg alignment scan. No cases of physeal bar formation were identified in the femur. Conclusion High resolution 3T MRI scan taken 12 months after transphyseal ACL reconstruction in a genuine paediatric population demonstrated two tibial physeal bar formations (6.6% incidence) and no femoral physeal bars. Neither of the two cases exhibited angular deformity or limb length discrepancy after 12 months. Central physiological closure of the tibial physis was commonly seen in this age group and may be easily confused with physeal bar formation.

Transphyseal ACL Reconstruction in Skeletally Immature Patients: Quantification of Physeal Damage Using a 3D MRI Simulation Model Study

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Summary:
During transphyseal anatomic Anterior Cruciate Ligament (ACL) reconstruction in patients with open growth plates, physeal damage should be minimized. This 3D MRI simulation model study identified that the maximum distal femoral physeal (DFP) and proximal tibial physeal (PTP) damage was obtained when drilling larger and less vertical tunnels at ACL anatomical reconstruction.

Data:
Purpose During transphyseal anatomic Anterior Cruciate Ligament (ACL) reconstruction in patients with open growth plates, physeal damage should be minimized. The orientation of tunneling that minimizes distal femoral physeal (DFP) and proximal tibial physeal (PTP) damage has been a topic of discussion. The objective of this study was to describe the physeal damage depending on the tunnel orientation in a three-dimensional (3D) model of transphyseal anatomic ACL reconstruction. Methods Eighty magnetic resonance images (MRI) from patients aged 10 to 17 were obtained and randomly sampled from the institutional database, with a homogeneous distribution of age and sex. A de novo software was developed to obtain 3D models of the distal femur, DFP, proximal tibia and PTP. In each model, the femoral and tibial ACL footprints were determined as established in cadaveric and imaging studies by previous authors. Drillings were simulated using 7, 8, 9- and 10-mm drills, starting from the ACL footprint point at every possible angle within a 90° cone. The angles were defined considering the zero vector (0°, 0°) as perpendicular to the ACL footprint. Physeal injury for each pair of angles and each drill size was determined. Damage was expressed as a percentage of the total growth plate volume. The segmentation, measurement, and statistical analysis were developed in MATLAB software. Statistical analysis was conducted using Student’s t test, one-way ANOVA, Mann Whitney and Kruskal-Wallis test. Statistical significance p<0.05. Results A total of 43 knees with open femoral and tibial growth plates were obtained, with a median of age of 13 (IQR 10-17), 59.6% men. Another 52 knees with only femoral open growth plate were obtained, with a median age of 12 (IQR 10-17), 60.5% men. Maximum DFP damage was obtained when drilling more horizontally (15° cephalic and 70° anterior) with a 10-mm drill, (13.79% [12.65-14.93]). The maximum femoral physeal injury was statistically different between drill sizes (p<0.001). There were no differences concerning sex (p = 0.21) or age (p = 0.086). Less than 7% femoral DFP damage was obtained with a more vertical tunnel (>15° cephalic and <70° anterior). At PTP maximum physeal damage was obtained when drilling more obliquely (10° medially and 25° anterior) with a 10-mm drill (6.63% [5.57 - 7.68]). The maximum tibial physeal damage was statistically different between drill sizes (p < 0.01). There were statistically significant differences between ages (p = 0.004) but without differences between sexes (p = 0.29). Less than 5% tibial physeal damage was obtained with a more medial and vertical tunnel (25° medially and 10° anterior). Conclusions This 3D MRI simulation model study identified that the maximum DFP and PTP damage was obtained when drilling larger and less vertical tunnels at ACL anatomical reconstruction, regardless of sex, with a larger damage of the DFP volume. If more vertical tunnels are made, less than 7% of femoral and tibial growth plates are damaged, regardless of the diameter of the tunnel.