Dynamic Evaluation of Pivot-Shift Kinematics in Physeal-Sparing Pediatric Anterior Cruciate Ligament Reconstruction Techniques

Mark Sena, James Chen, MD, Ryan Dellamaggioria, MD, Dezba G. Coughlin, PhD, Jeffrey C. Lotz, PhD, Brian T. Feeley, MD

Mark Sena
PhD candidate, Orthopaedic Bioengineering Lab

Advisers: Jeffrey Lotz, Brian Feeley

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Pediatric ACL injuries: non-operative vs. operative risks

avoiding or delaying surgery
recurrent instability
inability to return to play
meniscus / chondral damage
Lawrence 2011, Millet 2002

traditional (trans-physeal) ACL-R
varus / valgus deformity
tibial recurvatum
leg length discrepancy
Kocher 2002 (Hendicott survey)
Koman 1999, Lipscomb 1986
...(trans) fixation hardware
...large tunnels (>7% physis)
...graft overtensioning

Physeal-sparing ACL reconstruction: good outcomes, but...best choice?

AE (anatomical)
TT (trans-physeal)
ITB (iliotibial band)


Research question: How do Ped's techniques affect dynamic stability?

Pivot-shift test for rotational stability
Axial force, valgus and rotary torques
Flexion → subluxation / reduction

Clinical sign of symptomatic instability
Designed to mimic ‘giving way’
Galway 1972
+ Pivot correlates with poor outcome

However, low sensitivity in the clinic
patient guarding, depends on IT-band
Bach 1988
poor reliability, various techniques
Noyes 1991
Hypothesis: The AE technique best restores native pivot-shift kinematics

...as determined by four outcome variables

- Anterior Displacement (AD) [mm]
- Internal Rotation (IR) [deg]
- Posterior Translational Velocity (PTV) [mm/s]
- External Rotational Velocity (ERV) [deg/s]

...as determined by a “Knee Stability Index”
combines AD, IR, PTV, ERV into a single value (KSI)

MPSD Experimental Design: ACL intact, transected, reconstructed

- 6 knees, 5 conditions
  - intact, ACL-transected
  - AE, TT, ITB (randomized)

- position spring endpoints
  - femur: antero-lateral
  - tibia: postero-lateral

- perform test per condition
  - passive flexion (baseline)
  - flexion with device (3x)

- external fixator (Synthes)
  - attach spring to tibia / femur

- Optotrak™ motion capture
  - measure joint motion
  - measure spring position
  - load cell (not shown)
  - measure forces / moments

- spring (constant tension)
  - supplies forces / moments
Anterior Displacement (AD) Internal Rotation (IR)

Posterior Translation Velocity (PTV) External Rotational Velocity (ERV)

Knee Stability Index (KSI):

In summary...

All techniques improved stability metrics
- reduced deficient values by 18-78%
- only TT did not significantly reduce ERV

Iliotibial Band (ITB) reconstruction
- over-constrained AD (-52%) and IR (-38%)
- KSI (0.8)

Partial Trans-Tibial (TT) reconstruction
- best restored AD (5%) and IR (-6%)
- highest KSI (13.3)

All Epiphyseal (AE) reconstruction
- best restored PTV (-9%) and ERV (1%)
- lowest KSI (-4.0)
In summary...

Limitations
- Adult specimens for Peds techniques
- Time zero study
- MPSD requires (gentle) manual flexion
- MPSD not yet validated by others

Conclusions
- Operative treatment → good outcomes
- Kinematics depend on technique
- ITB extra-articular constraint … further study
- AE (most anatomic) improved dynamic stability

Key references and Acknowledgements

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