Biomechanical Comparison of Single Tunnel-Double Bundle and Single Bundle Anterior Cruciate Ligament Reconstructions

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INTRODUCTION

- Prevention of debilitating osteoarthritic changes and restoration of knee joint stability following an anterior cruciate ligament (ACL) rupture remains a subject of immense importance in sports medicine research.
- Anatomic double bundle ACL reconstruction is a technically challenging procedure associated with longer operation time, higher cost and complications with revision surgery.[1]
- Reproducing the ACL anatomy by using a single tibial and femoral tunnel could potentially overcome these limitations.

OBJECTIVE

- Investigate the effectiveness of single tunnel-double bundle (STDB) ACL reconstruction which uses a single tibial and femoral tunnel in restoration of ACL intact knee kinematics and to compare these results to single bundle (SB) ACL reconstruction.

MATERIALS AND METHODS

- Kinematic responses of eight fresh-frozen human cadaveric knee specimens were determined using a robotic testing system.[2]
- Flexion angles
  - 0°, 15°, 30°, 60°, and 90°
- External loading conditions
  - Anterior tibial load (130 N),
  - Simulated quadriceps load (400 N), and
  - Combined torques (5 N·m valgus and 5 N·m internal tibial torques)
- The experimental protocol is summarized in the flow chart (Figure 1).
- Knee conditions
  - ACL Intact
  - ACL Deficient
  - SB ACL reconstructed (Figure 2a)
  - STDB ACL reconstructed (Figure 2b, 3)
- Same femoral and tibial tunnels as well as the same quadruple hamstring tendon graft were used for both the reconstructions.
- Statistics
  - One-way repeated measures analysis of variance (ANOVA) and Student-Newman-Keuls tests were used.
  - Differences were considered statistically significant at $P < 0.05$.

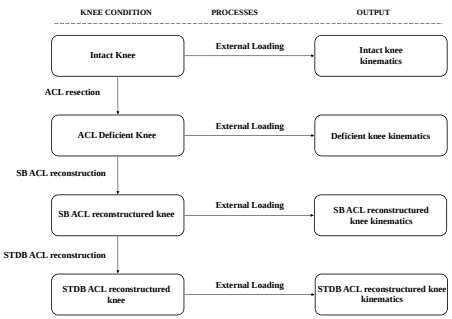

Figure 1. Experimental testing protocol

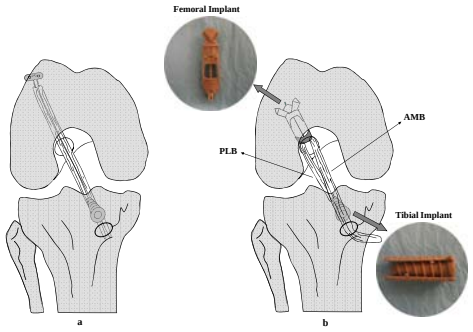

Figure 2. a) SB and b) STDB ACL reconstructions. AMB, anteromedial bundle; PLB, posterolateral bundle.

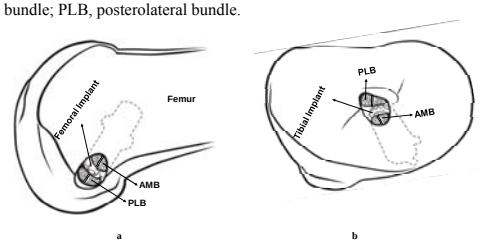

Figure 3. Schematic illustration of **a**) femoral implant and the separation of the two bundles in the femoral tunnel **b**) tibial implant and the separation of the two bundles in the tibial tunnel. AMB, anteromedial bundle; PLB posterolateral bundle.

RESULTS

- STDB ACL reconstruction was able to closely restore the intact knee anterior tibial translation (ATT) at low flexion angles (≤30°) ($P > 0.05$). On the contrary, SB ACL reconstruction resulted in significantly greater ATT in response to anterior tibial load (Figure 4) and simulated quadriceps load (Figure 5).

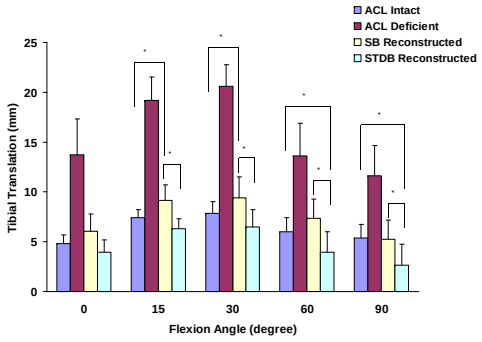

Figure 4. Anterior tibial translation under anterior tibial load in the four different knee conditions. Anterior tibial translations of the ACL deficient knee were significantly different from the intact, single bundle ACL reconstructed, and single tunnel-double bundle ACL reconstructed knee at all flexion angles. Error bars represent SD. *, P < 0.05. Recon, reconstruction.

- Both SB and STDB ACL reconstructions were capable of closely restoring ACL intact knee ATT under combined torques.
- The internal tibial rotations of the ACL intact knee were not significantly different ($P > 0.05$) from both SB and STDB ACL reconstructed knee at all selected flexion angles under the three external loading conditions.

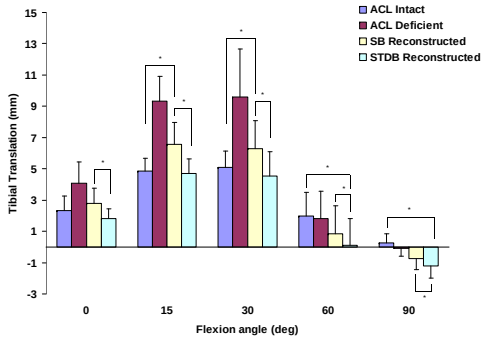

Figure 5. Tibial translation under simulated quadriceps load. Tibial translations of the ACL deficient knee were significantly different from the ACL intact, SB, and STDB ACL reconstructed knee at all flexion angles. Anterior tibial translation (+)/ Posterior tibial translation (-). Error bars represent SD. *, P < 0.05.

CONCLUSIONS

- STDB bundle ACL reconstruction can closely restore the intact knee kinematics under an anterior tibial load and simulated quadriceps load at low flexion angles (≤30°)
- The STDB technique introduced in this study is capable of reproducing both the functional bundles of the ACL by creating a single femoral and tibial tunnel
- Both ACL graft bundles were fixed at 0° which may have caused over tightening of the AM bundle at high flexion angles.
- Combined internal and valgus torques are an inefficient loading condition for investigating the rotational stability in cadaveric specimens.
- STDB is similar to the more familiar SB ACL reconstruction and could be an alternative to the technically demanding double tunnel-double bundle ACL reconstruction.
- Patient follow-up studies need to be performed to analyze the long term benefits of STDB ACL reconstruction.

REFERENCES

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2. Yoo J D et al. Am J Sports Med. 2005;33 (2):240-246.

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