Introduction

- Graft tunnel mismatch is a complication of ACL reconstruction that occurs when either the tibial tunnel is too long or short.
- The incidence of graft tunnel mismatch in ACL reconstruction has been reported to be as high as 26%
Introduction

• Knowing the length of the native ACL may help to decrease this complication.
  – Hypothesis – pre-operatively determine the native ACL length based on lateral radiographic landmarks.

Materials and Methods

• Native ACL length was measured percutaneously.
• A spinal needle was inserted on top of the ACL until it reached the origin at the back wall.
• The spinal needle was scored at the insertion of the of the ACL on the tibia with a arthroscopic grasper, and the distance from tip of needle to the score was measured.

• This measurement of the ACL was recorded and compared to a lateral X-Ray radiographic landmark.
• We compared the length of the native ACL to the depth of the femoral notch – Blumensaat’s line.

• The native ACL length was always obtained first, then Blumensaat’s line second, as not to bias the examiner in their measurement.
• All X-ray measurements where performed using the GE Centricity® system.
• The patellar ligament (PL) was measured clinically in the OR with the knee flexed to 90°.

• IRB Approved Retrospective Study
• 138 total native ACL’s measured.
• 130/138 had lateral X-rays, & a corresponding Blumensaat’s line (BL) measurement.
• 66/71 Male patients
• 64/67 Female patients

• Mean Percent Difference (MPD) – represents the percentage difference of BL to the native ACL length.
  – A perfect match between BL and the native ACL results in a MPD of 0%.
• Correlation (Corr) – Correlations between BL & ACL as well as PL & ACL were calculated.
  – >0.8=excellent
  – <0.2=poor
Average Lengths of BL, ACL, & PL

Mean Percent Difference BL & ACL

Correlation BL & ACL and PL & ACL

Discussion

- Our results demonstrate the length of Blumensaat’s line on lateral X-ray, is virtually equivalent to the length of the native ACL.

Limitations

- The measurements were obtained and recorded retrospectively.
- The measurement of the native ACL was obtained via a percutaneous technique.
- Finally, the percutaneous measurement best represents the length of the anteromedial bundle of the ACL.

Discussion

- The difficulty with MRI measurement is the inconsistent quality of MRI (open vs. closed).
- We feel that lateral X-ray is more reproducible and more cost-effective.
- Additionally, the actual length of the native ACL was measured (gold standard), as opposed to obtaining this measurement from an image.
Discussion

• This data helps to accurately, and easily predict the native length of the ACL in a patient with a torn ACL.
• Knowing this information prior to surgery, may allow for more accurate acquisition of bone-patella-tendon-bone (BPTB) allograft tissues.
• Consequently, regardless of allograft or autograft, calculation of the native ACL may help to prevent graft tunnel mismatch.

Conclusion

• Therefore, as a general rule, regardless of age and sex, the length of Blumensaat’s line is nearly equal to the length of the native ACL.

Abstract

• **Hypothesis:** Pre-operatively template ACL reconstruction and have graft tunnel mismatch (GTM) <5mm.
• **Materials & Methods:** 20 prospective patients underwent ACL reconstruction with BPTB autograft. All ACL reconstructions were done anatomically with independent tunnels.
• **Results:** Using the mathematical formula presented, the average GTM is 0.6mm.
• **Conclusion:** This method of pre-operative templating ACL reconstruction with BPTB autograft is effective in eliminating graft tunnel mismatch.

Introduction

• Allografts as well as an autograft in a patient with patella baja or alta can increase the likelihood of graft tunnel mismatch1,4,6,9.
• Accurately predicting the native ACL length preoperatively would help to decrease the likelihood of graft tunnel mismatch.
**Materials & Methods**

- 20 Prospective BTB autograft ACL reconstructions
- Prior research demonstrates that Blumensaat’s line and the ACL are, as a general rule, the same length.
- Therefore, we used the following mathematical formula to predict the tibial tunnel length, assuming we predetermined the femoral tunnel length

\[
\text{TTL} = \text{OGL} - (\text{BL} + \text{FTL})
\]

**Calculation of Tibial Tunnel (TT)**

\[
\text{TT} = \text{OGL} - (\text{BL} + \text{FT})
\]

**Overall Graft Length (OGL)**

**Materials & Methods**

- Every Patient received lateral X-rays prior to surgery
- BL and Patellar Ligament length were measured off of lateral X-rays
- Overall Graft Length, preoperatively, was calculated by adding 40mm to patellar ligament length, from lateral X-ray
- The additional 40mm was for each 20mm bone plug

**Materials & Methods**

- Pre-operative and intra-operative measurements where recorded for Blumensaat’s Line (BL) and reconstructed ACL length (rACL), Patellar ligament length (PPL/IPL), Overall Graft Length (PGL/IGL), Tibial Tunnel Length (PTT/ITT), and Graft Tunnel Mismatch (GTM).
- GTM was defined as any amount of patellar bone plug extruding from tibial tunnel at time of fixation.
Materials & Methods

- Averages, Absolute Differences, Mean Percent Difference (MPS), Mean Percent Error (MPE), as well as correlation coefficients were calculated for all the measurements.
- MPS is the percent difference between the preoperative and intra-operative measurement.
- MPE is the difference between the preoperative and intra-operative measurements, as percentage of the intra-operative measurement.

Results

- Absolute Difference of Pre-operative and Intra-operative Measurements (mm)
- Mean Percent Difference of Pre-operative and Intra-operative Measurements (%)
- Mean Percent Error of Pre-operative and Intra-operative Measurements (%)
- Correlation Between Pre-operative and Intra-operative Measurements

*** Welcome***
Joyner, Roth 2013 – Prospective GTM

- 17 Patient's enrolled
  - 11 male, 6 female
  - Ave BL – 30.8mm
  - Ave ACLr – 31.4mm
  - BL/ACLr CC – 0.81
  - MPS – 99.2%
  - GTM = 1.65mm

Discussion

- These results demonstrate that the length of the reconstructed ACL, using anatomic technique, as a general rule, is the same length of Blumensaat’s line.
- Additionally, using the method of preoperative templating ACL reconstruction with BTB autograft, presented can eliminate graft tunnel mismatch.

Discussion - Limitations

- Small sample size
  - Prospective series, large enough sample size for appropriate statistics
- Variability in lateral knee X-ray
  - Future research can demonstrate ideal flexion angle for more accurate patellar tendon length
- Use of BTB autograft
  - Future research can demonstrate the use of allograft with this method of templating

Conclusion

- This method of pre-operatively templating an ACL reconstruction using a lateral knee X-ray, can effectively eliminate graft tunnel mismatch when using BTB autografts.
  - A secondary outcome measure demonstrates that, as a general rule, the reconstructed ACL is the same length as Blumensaat’s line.
Avoid Graft Tunnel Mismatch in Allograft Anterior Cruciate Ligament Reconstruction

The Blumensaat’s Line Method

Karim A. Meijer, MD; Michael Saper, DO; Patrick Joyner, MD, MS; Wei Lu, PhD; James R. Andrews, MD; Charlie Roth, MD

Problem

• Graft Tunnel Mismatch (GTM)
  – Reported in 26% of cases using bone-patellar tendon-bone (BTB) autografts
  – May be even higher in BTB allograft cases

During Surgery...

AVOID IT
• GL – 50
  – Kenna et al 1993
• “N+7”
  – Miller et al 1996
• “N+2”
  – Olszewski et al 1998
• Calibrated drill
  – Hartman Arthroscopy 1999
• Single Bone Block
  – Grawe et al Arthroscopy Tech 2014

DEAL WITH IT
• Tie Over a Post
• Cut a Trough & Staple
• Recess it
• Free Bone Block
  – Novak et al Arthroscopy 1996
  – Fowler Arthroscopy 1998
• Twist it
  – Augé et al Arthroscopy 1999
  – Verma et al AJSM 2003
• Fold it
  – Barber Arthroscopy 2000

Hypothesis

• Blumensaat’s line (BL) from the recipient’s lateral knee radiograph can predict the desired length for the tendinous portion of a BTB allograft in an ACLR as well as the tibial tunnel length

Study Design

• Cadaveric Study
• A Priori Power Analysis
  – β (0.85)
• Significance
  – α (0.05)

Methods

• Length-specific allografts for the tendinous portion of the grafts were ordered by adding 20 mm to the length of BL based on a lateral knee X-Ray.
• Eighteen ACLRs using the length-specific BTB allografts were performed on each cadaveric specimens using an independent femoral tunnel technique (accessory medial portal).
• Tibial Tunnel Length (TTL) was predicted by subtracting BL and femoral tunnel length (FTL) from the overall graft length (OGL).
• GTM was recorded at the end of each case. Statistical analysis compared overall results with the gold standard of 0 mm of GTM.
Meijer-Roth 2017 – Cadaveric Length Specific Allograft

• Results
  – Ave BL – 28.1 ± 2.25
  – MPS BL/ACLr – 105.2%
  – MPD BL/ACLr – 5.2%
    • ACLr 5.2% longer than BL (=1.3mm)
  – BL Intra-CC – 0.81
  – BL Inter-CC – 0.63
  – Mean GTM -0.9mm ± 3.15mm

18 Cadaver Knees

Calibrated Radiograph

25 mm Marker Ball

Formula

\[ \text{TTL} = \text{OGL} - \text{FTL} - \text{BL} \]

Assumptions

• Patellar Ligament = Blumensaat’s Line + 20 mm
• Femoral Bone Plug = 20 mm
• Tibial Bone Plug = 20 mm
• Femoral Tunnel ~ 25 mm
Results - GTM

• Mean GTM was -0.9 mm
  – (SD ± 3.15 mm, range, -7.5 to +4.5 mm)
  – Negative means graft was recessed

• No statistically significant difference between the BL Method and the gold standard (P=0.45)

Results - BL

• Average length of BL was 28.1 mm
  – (SD ± 2.25 mm range, 25-32).

• Intra-correlation and inter-correlation coefficient between the three physicians measuring BL was 0.81 and 0.63, respectively (>0.8=excellent, 0.6-0.79=good, 0.4-0.59=average, 0.2-0.39=fair, <0.2=poor).

Results – BL vs. IAD

• BL and the IAD (Intra-articular distance between femoral and tibial apertures) demonstrate a mean percent similarity and mean percent difference of 105.2% and 5.2%, respectively*

• IAD was on average 5.2% longer than BL or 1.3 mm

* (when the length of BL is considered the gold standard) Joyner et al AAOS 2015

AANA 2016
Meijer-Roth 2017 – Cadaveric Length Specific Allograft

• 18 matched pair cadavers
• All got lateral x-rays with marker ball
• Allograft lengths ordered
  – BL + 20 mm
• Pre-op assumptions
  – Femoral Bone Plug = 20 mm
  – Tibial Bone Plug = 20 mm
  – Femoral Tunnel = 25 mm
  – Tibial Tunnel = 35 mm

Conclusion

1. The BL Method can accurately predict the desired length for the tendinous portion of a BTB allograft as well as the TTL.
2. GTM can be avoided during arthroscopic BTB allograft ACLR.
3. Formula

  BTB Allograft Tendon Length = BL + 20 mm
  TTL = OGL – FTL - BL

Significance of Study

• This study provides surgeons the ability to preoperatively plan an ACLR using a BTB allograft with independent tunnels. As some surgeons move toward independent tunnel ACLRs, femoral tunnel lengths have become shorter; therefore, the potential for GTM has increased.
• To our knowledge, no study has previously tested their hypothesis or algorithm for preoperatively ordering length-specific BTB allografts
Avoiding Graft Tunnel Mismatch

Introduction

Although a majority of ACL reconstructions are successful, complications occur.
• Graft tunnel mismatch, in particular, is an intra-op complication that can compromise graft fixation.
  – Reported as high as 26%

Introduction

• Allografts as well as an autograft in a patient with patella baja or alta can increase the likelihood of graft tunnel mismatch.
• Knowing the length of the native ACL may help to decrease this complication.

Conclusions

• BL is NOT identical to native ACL,
  – I add 5mm to my TT length as additional safeguard
• I drill tibia first
  – May help to minimize femoral tunnel length
• I built an i-phone app for those that don’t like to do the math
  – PerfectACL
“By failing to prepare, you are preparing to fail.”
- Benjamin Franklin