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Peter T. Scheffel, Heath B. Henninger and Robert T. Burks

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Relationship of the Intercondylar Roof and the Tibial Footprint of the ACL

Implications for ACL Reconstruction

Peter T. Scheffel,*† MD, Heath B. Henninger,†‡ PhD, and Robert T. Burks,† MD
Investigation performed at the University of Utah, Salt Lake City, Utah

Background: Debate exists on the proper relation of the anterior cruciate ligament (ACL) footprint with the intercondylar notch in anatomic ACL reconstructions. Patient-specific graft placement based on the inclination of the intercondylar roof has been proposed. The relationship between the intercondylar roof and native ACL footprint on the tibia has not previously been quantified.

Hypothesis: No statistical relationship exists between the intercondylar roof angle and the location of the native footprint of the ACL on the tibia.

Study Design: Case series; Level of evidence, 4.

Methods: Knees from 138 patients with both lateral radiographs and MRI, without a history of ligamentous injury or fracture, were reviewed to measure the intercondylar roof angle of the femur. Roof angles were measured on lateral radiographs. The MRI data of the same knees were analyzed to measure the position of the central tibial footprint of the ACL (cACL). The roof angle and tibial footprint were evaluated to determine if statistical relationships existed.

Results: Patients had a mean ± SD age of 40 ± 16 years. Average roof angle was 34.7° ± 5.2° (range, 23°-48°; 95% CI, 33.9°-35.5°), and it differed by sex but not by side (right/left). The cACL was 44.1% ± 3.4% (range, 36.1%-51.9%; 95% CI, 43.2%-45.0%) of the anteroposterior length of the tibia. There was only a weak correlation between the intercondylar roof angle and the cACL (R = 0.106). No significant differences arose between subpopulations of sex or side.

Conclusion: The tibial footprint of the ACL is located in a position on the tibia that is consistent and does not vary according to intercondylar roof angle. The cACL is consistently located between 43.2% and 45.0% of the anteroposterior length of the tibia. Intercondylar roof–based guidance may not predictably place a tibial tunnel in the native ACL footprint. Use of a generic ACL footprint to place a tibial tunnel during ACL reconstruction may be reliable in up to 95% of patients.

Keywords: ACL; femoral roof angle; impingement; ACL repair

Failure of an anterior cruciate ligament (ACL) graft after reconstruction remains a concern. The location of graft placement, and its relationship to subsequent failure, has been studied extensively.[§] Impingement of the graft on the intercondylar roof is one presumed mode of failure and is thought to cause loss of extension, pain, knee effusion, graft failure, and recurrent instability.[1,14-16] Iriuchishima et al[17,18] and Bedi and Altchek[2] have suggested that proper placement of the ACL graft should be within the native ACL footprint to prevent impingement and have referred to this methodology as the "anatomic" reconstruction technique.[10] Others recommend placement based on the intercondylar roof angle to avoid impingement on the femur.[12,13,16] By either method, the anatomy dictates the placement of the graft and suggests a possible variable placement in ACL reconstruction.

Impingement of the graft on the intercondylar roof is thought to be caused by placement of the graft too far anterior on the tibial plateau, allowing the graft to contact the roof during knee extension. Anatomic variation may complicate this condition, obscuring the requirements for consistent placement of the graft to avoid impingement.[12-14,16] It is reported that knees with more vertical roof angles, and/or physiological hyperextension, require the graft to be placed more posterior on the tibia to prevent impingement against the roof.[12] Additionally, it is recommended that the tibial tunnel be aligned parallel to the intercondylar roof when the knee is in maximum extension. If the native ACL position is dictated by anatomic barriers such as the intercondylar roof, then patients with a steep roof angle should have a native tibial footprint relatively

[§]References 6-9, 12, 13, 16, 17, 19, 21.

*Address correspondence to Peter T. Scheffel, MD, Department of Orthopaedics, University of Utah, 1326 South 1000 East, Salt Lake City, UT 84105 (e-mail: petescheffel@hotmail.com).
†Department of Orthopaedics, University of Utah, Salt Lake City, Utah.
‡Department of Bioengineering, University of Utah, Salt Lake City, Utah.

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posterior on the tibia. This would prevent contact of the ligament in full extension or even hyperextension. While the femoral side attachment is relatively well defined,[3,28] evidence of the relationship between all the anatomic factors is largely unknown. The assumption would be that an ACL reconstruction should follow anatomic cues. By this methodology, patient-specific measurements are required because maximal knee extension and intercondylar roof angles vary between patients.[12,13] However, patient-specific measures have not been widely accepted.

Interestingly, the footprint of the ACL on the tibial plateau has been shown to remain relatively consistent between patients despite age and sex, although roof angles have been found to vary.[4,12,13,26] This suggests that the native tibial footprint does not change relative to the roof angle, or the degree of knee extension, and roof angle measurements alone may not be reliable to guide ACL reconstructions.

The purpose of this study was to identify the center of the tibial footprint, and its variability, in knees with intact ligaments (using magnetic resonance imaging [MRI]). Additionally, intercondylar roof angles were measured in the same knees (from lateral radiographs), and statistical tests were undertaken to determine if a relationship existed between the native ACL footprint position and the intercondylar roof angle in "ligamentously intact" knees.

MATERIALS AND METHODS

General Overview

This retrospective study was approved by the Institutional Review Board of the University of Utah (#55828). Imaging data obtained during the normal course of care were reviewed from patients who presented with complaints relating to the knee in 2011. Patients were included if they met the following criteria: (1) a lateral knee radiograph was obtained, and (2) an MRI scan of the same knee demonstrated the absence of a ligamentous abnormality or fracture. Meniscal and chondral injuries did not exclude the patient from the study.

Radiographic Technique and Interpretation

Lateral plain radiographs were obtained by placing a 14 × 17–inch cassette next to the knee, centered so that the distal femur and proximal tibia were captured. The beam was directed medial to lateral, with the appropriate amount of rotation to allow for condylar overlap. Any image demonstrating a fracture or >6 mm of condylar offset was excluded from the study. This exclusion criterion was consistent with previous studies performed to evaluate intercondylar roof angles.[13,16]

Per the technique of Howell and Barad,[13] the intercondylar roof angle was measured. All image-based measurements were performed by the lead author (P.T.S.) with tools available in a picture archiving and communication system (PACS) (iSite PACS v3.6, Philips Healthcare, Andover, Massachusetts). The intercondylar roof angle was measured between 2 lines, 1 parallel to the posterior cortex of the femur and 1 parallel to the intercondylar roof (Figure 1A). In a previous study, Howell and Barad[13] showed the roof angle to be independent of knee extension; therefore, criteria for specific knee extension angles were not enforced as exclusion criteria.

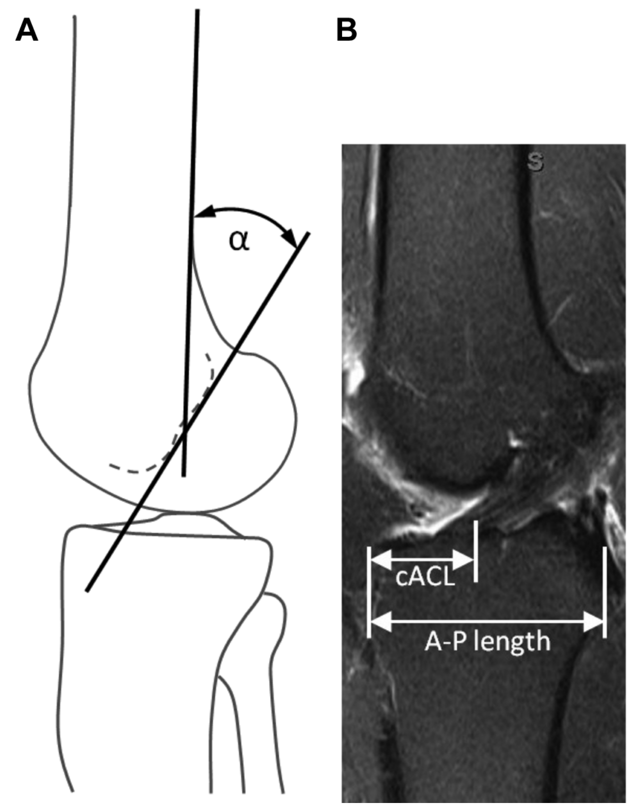

Figure 1. Schematic of relevant measures (adapted from Howell and Barad[13]). (A) Roof angle (α) is measured between a line parallel to the posterior cortex of the femur and a line parallel to the intercondylar roof. (B) Length of the tibia is defined between the anterior and posterior edges of the tibia in the magnetic resonance imaging slice where the anterior cruciate ligament (ACL) is widest. Center of the ACL (cACL) is the midline tibial insertion with respect to the anterior border.

MRI Technique and Interpretation

All MRI series were performed with a Siemens Avanto 1.5-T superconducting magnet (Siemens AG, Erlangen, Germany). Imaging was performed from medial to lateral, and sagittal imaging produced scans consisting of 3-mm slices. Each series was reviewed by the lead author (P.T.S.) and musculoskeletal radiologists to ensure ligamentous continuity and the absence of fractures. Any patient having a displaced fracture or a complete or partial ligamentous rupture was excluded.

The tibial insertion of the ACL was determined by evaluating the T1- and T2-weighted sequences on the sagittal projection. Each MRI series was reviewed to determine the sagittal slice that represented the largest ACL tibial footprint. From this image, the center of the tibial insertion of the ACL (cACL) was measured as a percentage of the anteroposterior (AP) length of the tibial plateau (Figure 1B). This technique was consistent with previous studies[13,26] but cannot account for variation in the mediolateral and oblique aspects of the footprint.[20]

Statistical Analysis

Two observers (P.T.S., H.B.H.) evaluated a subset of 15 radiographs and MRI series to determine the interrater reliability of the techniques. One observer (P.T.S.) repeated the data set after 4 weeks to determine intrarater reliability. Intraclass correlation coefficients (ICCs) were used to evaluate consistency between observers and within the same observer.

Intercondylar roof angles were evaluated with a Kolmogorov-Smirnov test to ensure normality of the sample population. From the normally distributed population, only patients above and below 1 standard deviation (SD) of the mean were selected for further analysis. This produced 2 subpopulations representing the extremes of the range of intercondylar roof angles, highlighting differences between the fringes of the same population and allowing discrete statistical analyses to be performed within the same overall population.

The Pearson correlation coefficient was calculated to determine if relationships existed between the tibial footprint (tibial length, cACL) and roof angle. Strength of correlation was assessed as follows: ≤0.3 = weak, if any; 0.3-0.5 = low; 0.5-0.7 = moderate; 0.7-0.9 = high; ≥0.9 = very high.[11] Discrete comparisons between subpopulations (sex, side [right/left], upper/lower SD) were performed with 2-tailed independent *t* tests with significance at $P \leq .05$. All data are presented as mean ± SD (range).

RESULTS

Fifteen images were examined by each of the observers. Interobserver correlation coefficients for roof angle measurements exhibited strong agreement[5] (ICC, 0.714; 95% confidence interval [CI], 0.148-0.904) as well as strong agreement for cACL (ICC, 0.782; 95% CI, 0.350-0.927). Intrarater reliability was excellent for roof angle (ICC, 0.958; 95% CI, 0.879-0.986) and strong for cACL (ICC, 0.794; 95% CI, 0.387-0.931). Given the high ICCs, measurements of the variables in this study are considered reliable.

The population of 138 patients had a mean age of 40 ± 16 years (range, 18-72). The roof angles, by subpopulation, are found in Table 1. The average intercondylar roof angle in 138 patients was 34.7° ± 5.2° (range, 23°-48°; 95% CI, 33.9°-35.5°). The roof angle differed between male and female patients ($P = .005$), but no differences were detected by side (right/left, $P = .890$). By subpopulation (eg, female, right), no differences were detected within sex and between sides (both $P \geq .579$). Between sexes, within a side, no differences were detected on the right ($P = .099$), but differences were detected on the left ($P = .020$).

TABLE 1
Descriptive Statistics of Roof Angle by Subpopulation[a]

Group	Roof Angle, deg	*P*
All (N = 138)	34.7 ± 5.2 (23-48)	—
Sex		.005[b]
Female (n = 68)	33.4 ± 5.1 (24-47)	
Male (n = 70)	35.8 ± 5.1 (23-48)	
Side		.890
Right (n = 67)	34.6 ± 5.1 (23-47)	
Left (n = 71)	34.8 ± 5.4 (24-48)	

[a]Data are shown as mean ± standard deviation (range).
[b]Significant difference ($P \leq .05$).

The roof angles for all populations (all patients, sex, side, etc) were normally distributed (all $P \geq .143$). Accordingly, subpopulations with a roof angle ≤30° and ≥40° (±1 SD of the mean) were isolated for further analysis. The demographics of these 55 patients were as follows: 40 ± 17 years (range, 18-72), 26 female, 29 male, 26 right, 29 left. The cACL was reliably located at a position 44.1% ± 3.4% of the AP length of the tibia (95% CI, 43.2%-45.0%) (Figure 2B), as referenced from the anterior edge of the tibia.

For all patients, there was a low correlation between tibial AP length and roof angle ($R = 0.307$). When comparing the upper and lower SD populations, significant differences arose between male and female patients (all $P \leq .012$) (Figure 2A). No significant differences were found between upper and lower SD populations within a sex, within a side, or between sides (all $P \geq .061$).

For all patients, there was a weak correlation between cACL and roof angle ($R = 0.106$) (Figure 2B). By subpopulation, female and male patients also showed a weak correlation (R = 0.075 and 0.215, respectively). When comparing the upper and lower SD populations, no significant differences arose between sexes or sides, within or between the upper and lower SD groups (all $P \geq .097$) (Figure 2C).

DISCUSSION

Summary of Findings

Analyses showed that in outlier populations of roof angle, those above and below 1 SD of the mean, the cACL was reliably located at a position 44.1% ± 3.4% of the AP length of the tibia (95% CI, 43.2%-45.0%) (Figure 2B), as referenced from the anterior edge of the tibia. Additionally, the cACL is independent of roof angle. These findings were not affected by sex or side, but male patients generally had a longer tibial plateau than female patients (Figure 2A).

Comparison to Previous Studies

Staubli and Rauschning[26] measured the intercondylar roof angle on MRI scans and cryosections of the extended knee.

The average roof angle from cryosections was 39.8° (range, 35°-44°), which varies considerably from the present study (34.7° ± 5.2°; range, 23°-48°) given the relatively small variance of the populations. This may be attributed to differences in data collection between histological sections and radiographs. While multiple studies have quantified roof angle to be in the range of 35° to 38°,[4,13,23,25,26] using varied techniques, these are only slightly lower than the measurements presented herein. The low variance in the present study, ±5°, is in agreement with previous studies, affirming that the present findings are reliable and within the error of prior studies.

Previous studies did not detect significant differences in roof angle by sex,[4,13] whereas the present study detected that female patients (33.4° ± 5.1°) had a lower intercondylar roof angle than male patients (35.8° ± 5.1°) (P = .005) (Table 1). These differences may not have been detected previously because of smaller sample sizes. A narrow notch, as present in female patients, has been identified as a risk factor for the failure of ACL reconstructions[27] but was not related to roof angle and therefore was not within the scope of the present study. No differences were detected across the whole population between right and left knees. Expectedly, the length of the tibial plateau did show significant sex differences (Figure 2A) in which male patients had a larger tibial plateau than female patients.

Recurvatum, in the setting of a more vertical intercondylar roof, has been postulated to result in an "unforgiving knee" where the steep angle creates impingement and heightens the risk for ACL graft ruptures. Howell and Barad[13] found considerable variability in maximal knee extension between patients, ranging from 2° of flexion to 30° of hyperextension. They determined that the degree of knee extension was not a reliable indicator of roof angle and concluded that "a knee with a given degree of knee extension was almost as likely to have a vertical roof as a horizontal roof." Accordingly, the present study did not include knee extension angle as an independent variable. Factors like screw home and laxity were not controlled for in the present study but could also contribute to premature graft failure. These factors likely do not influence the anatomic relationship of the intercondylar roof and the tibial plateau.

Another potential indicator of impingement may be the positioning of the ACL graft on the tibial plateau. Howell and Taylor[16] described the central position of an unimpinged ACL graft as 42% ± 2.8% of the AP dimension of the tibial plateau, as referenced to the anterior edge. Early measures of the central ACL footprint were 23 ± 4 mm from the most anterior aspect of the tibia.[24] More recently, the native ACL footprint has been measured as having a mean of 45.6% ± 6.5% in one study and 44% of the AP length in another,[23,26] where the anteromedial bundle and posterolateral bundle of the ACL insert at 41% ± 3% and 52% ± 3%, respectively.[20] In the present study, the cACL was reliably located at a position 44.1% ± 3.4% (range, 36.1%-51.9%; 95% CI, 43.2%-45.0%) (Figure 2B) along the length of the tibial plateau, as referenced from the anterior edge of the tibia. Utilizing this generic position for placement of a tibial tunnel might result in an unimpinged ACL graft per the definition of Howell and Taylor[16] despite not basing the tunnel location off of the respective intercondylar roof angle. A recent study by Mall et al[22] noted that "only modest agreement" exists

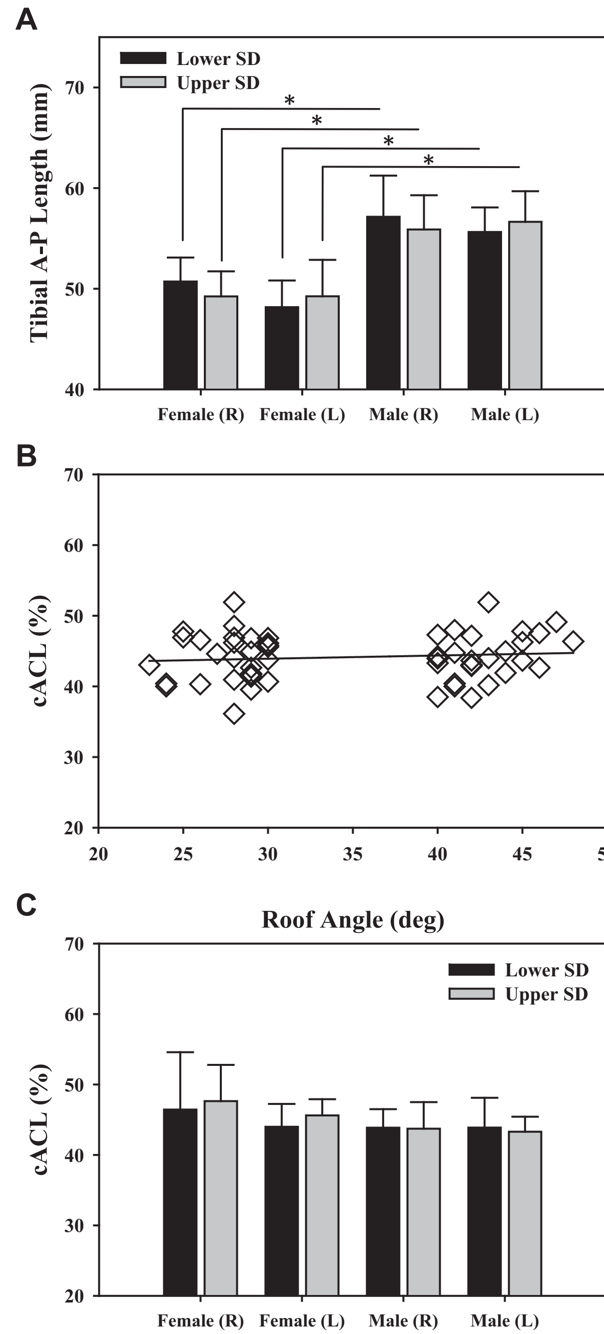

Figure 2. Tibial length and center of the tibial insertion of the anterior cruciate ligament (cACL) for upper and lower standard deviation populations. (A) The anteroposterior length of the tibia was shorter for female patients (*all $P \leq .012$); otherwise, there were no differences between or within groups (all $P \geq .061$). (B) The cACL had low correlation to roof angle (R = 0.106). (C) No statistical differences for cACL were detected between or within groups (all $P \geq .097$).

between numerous studies defining optimal tunnel placement. Their study highlighted how critical the tibial tunnel was in successful ACL graft placement, suggesting it may be more important than femoral tunnel placement in providing stability to the reconstructed knee.

Relationship of ACL Footprint and Intercondylar Roof Angle

The present study shows that the location of the cACL, 44.1% ± 3.4% of the AP length of the tibia, has a weak relationship to the intercondylar roof angle (α = 34.7° ± 5.2°; R = 0.106) (Figure 2B). These findings show that roof angle is independent of cACL location, and this does not change by sex or side (Figure 2C). Therefore, intercondylar roof guidance may be a less accurate method to predictably place a tibial tunnel within the native ACL footprint. This conclusion is strengthened by the use of the "outlier" populations, those above and below 1 SD of the mean, because even these disparate data points cannot detect any statistical differences. Use of a generic ACL tibial tunnel position during ACL reconstructions may be reliable in up to 95% of patients. However, in a population of 138 patients, the footprint was almost 16%.

The implications of these findings are as follows: (1) The location of the native ACL footprint is independent of roof angle, sex, side, or knee extension. (2) Placement of the tibial tunnel should target roughly 44% of the distance along the tibial plateau, as referenced to the anterior edge of the tibia as measured with MRI. (3) The accuracy of using intercondylar roof guidance to locate the native tibial footprint during ACL reconstruction remains unknown.

Limitations

Foremost, this study defined the relationship between femoral roof angle and tibial footprint in otherwise healthy knees. This study assumed that normal ACLs do not impinge and cannot conclude the source or mechanism of impingement in native or grafted ACLs if and when it exists. Factors like graft shape and diameter are likely critical in defining impingement. Additionally, all measures of cACL were referenced to the anterior edge of the tibia as seen in MRI. Accordingly, this relative definition of the ACL placement is required in cases where the stump of a ruptured ACL is not present during reconstruction. Further research is required to reliably define these criteria in the operating theater. Second, radiographic measures may be confounded by rotation of the extremity, but use of the "6-mm rule" ensured that all measurements were taken on radiographs that met standard requirements for preoperative planning. Similarly, sagittal plane scans from MRI may not perfectly section the tibial plateau such that the maximal length is visualized. Given the small SDs in length and cACL ($<$5%), these measures, along with the population size, are considered sufficient to detect any statistical relationships. Finally, correlation of bony landmarks between radiographs and MRI has yet to be defined. As a result, MRI-based measurements of the AP length through the widest section of the ACL cannot necessarily be directly translated to radiographs.

CONCLUSION

The intercondylar roof angle likely has no clinical relationship to the location of the central ACL footprint in knees without a bony deformity or ligament rupture. Use of a generic ACL footprint position (eg, with intraoperative fluoroscopy measurements) for a tibial tunnel during ACL reconstructions may be reliable in up to 95% of patients, although in a population of 138 patients, the footprint was almost 16% of the AP dimension of the tibia. Therefore, maintaining the footprint and using it to accurately position the tibial tunnel appear reliable.

REFERENCES

1. Aglietti P, Buzzi R, Giron F, Simeone AJ, Zaccherotti G. Arthroscopic-assisted anterior cruciate ligament reconstruction with the central third patellar tendon: a 5-8-year follow-up. *Knee Surg Sports Traumatol Arthrosc*. 1997;5(3):138-144.
2. Bedi A, Altchek DW. The ''footprint'' anterior cruciate ligament technique: an anatomic approach to anterior cruciate ligament reconstruction. *Arthroscopy*. 2009;25(10):1128-1138.
3. Bernard M, Hertel P, Hornung H, Cierpinski T. Femoral insertion of the ACL: radiographic quadrant method. *Am J Knee Surg*. 1997;10(1):14-21, discussion 21-22.
4. Buzzi R, Zaccherotti G, Giron F, Aglietti P. The relationship between the intercondylar roof and the tibial plateau with the knee in extension: relevance for tibial tunnel placement in anterior cruciate ligament reconstruction. *Arthroscopy*. 1999;15(6):625-631.
5. Fleiss JL, Levin B, Paik MC. *Statistical Methods of Rates and Proportions*. 3rd ed. Hoboken, New Jersey: John Wiley & Sons; 2003.
6. Fujimoto E, Sumen Y, Deie M, Yasumoto M, Kobayashi K, Ochi M. Anterior cruciate ligament graft impingement against the posterior cruciate ligament: diagnosis using MRI plus three-dimensional reconstruction software. *Magn Reson Imaging*. 2004;22(8):1125-1129.
7. Fung DT, Hendrix RW, Koh JL, Zhang LQ. ACL impingement prediction based on MRI scans of individual knees. *Clin Orthop Relat Res*. 2007;460:210-218.
8. Fung DT, Zhang LQ. Modeling of ACL impingement against the intercondylar notch. *Clin Biomech (Bristol, Avon)*. 2003;18(10):933-941.
9. Goss BC, Howell SM, Hull ML. Quadriceps load aggravates and roofplasty mitigates active impingement of anterior cruciate ligament grafts against the intercondylar roof. *J Orthop Res*. 1998;16(5): 611-617.
10. Hensler D, Van Eck CF, Fu FH, Irrgang JJ. Anatomic anterior cruciate ligament reconstruction utilizing the double-bundle technique. *J Orthop Sports Phys Ther*. 2012;42(3):184-195.
11. Hinkle DE, Wiersma W, Jurs SG. Correlation: a measure of relationship. In: *Applied Statistics for the Behavioral Sciences*. New York: Houghton Mifflin Company; 1998:120-121.
12. Howell SM. Principles for placing the tibial tunnel and avoiding roof impingement during reconstruction of a torn anterior cruciate ligament. *Knee Surg Sports Traumatol Arthrosc*. 1998;6 Suppl 1: S49-S55.
13. Howell SM, Barad SJ. Knee extension and its relationship to the slope of the intercondylar roof: implications for positioning the tibial tunnel in anterior cruciate ligament reconstructions. *Am J Sports Med*. 1995;23(3):288-294.
14. Howell SM, Clark JA. Tibial tunnel placement in anterior cruciate ligament reconstructions and graft impingement. *Clin Orthop Relat Res*. 1992;283:187-195.

15. Howell SM, Clark JA, Farley TE. Serial magnetic resonance study assessing the effects of impingement on the MR image of the patellar tendon graft. *Arthroscopy*. 1992;8(3):350-358.
16. Howell SM, Taylor MA. Failure of reconstruction of the anterior cruciate ligament due to impingement by the intercondylar roof. *J Bone Joint Surg Am*. 1993;75(7):1044-1055.
17. Iriuchishima T, Horaguchi T, Kubomura T, Morimoto Y, Fu FH. Evaluation of the intercondylar roof impingement after anatomical double-bundle anterior cruciate ligament reconstruction using 3D-CT. *Knee Surg Sports Traumatol Arthrosc*. 2011;19(4):674-679.
18. Iriuchishima T, Tajima G, Ingham SJ, Shen W, Smolinski P, Fu FH. Impingement pressure in the anatomical and nonanatomical anterior cruciate ligament reconstruction: a cadaver study. *Am J Sports Med*. 2010;38(8):1611-1617.
19. Jagodzinski M, Leis A, Iselborn KW, Mall G, Nerlich M, Bosch U. Impingement pressure and tension forces of the anterior cruciate ligament. *Knee Surg Sports Traumatol Arthrosc*. 2003;11(2):85-90.
20. Lorenz S, Elser F, Mitterer M, Obst T, Imhoff AB. Radiologic evaluation of the insertion sites of the 2 functional bundles of the anterior cruciate ligament using 3-dimensional computed tomography. *Am J Sports Med*. 2009;37(12):2368-2376.
21. Maak TG, Bedi A, Raphael BS, et al. Effect of femoral socket position on graft impingement after anterior cruciate ligament reconstruction. *Am J Sports Med*. 2011;39(5):1018-1023.
22. Mall NA, Matava MJ, Wright RW, Brophy RH. Relation between anterior cruciate ligament graft obliquity and knee laxity in elite athletes at the National Football League combine. *Arthroscopy*. 2012;28(8):1104-1113.
23. Miller MD, Olszewski AD. Posterior tibial tunnel placement to avoid anterior cruciate ligament graft impingement by the intercondylar roof: an in vitro and in vivo study. *Am J Sports Med*. 1997;25(6):818-822.
24. Odensten M, Gillquist J. Functional anatomy of the anterior cruciate ligament and a rationale for reconstruction. *J Bone Joint Surg Am*. 1985;67(2):257-262.
25. Scuderi GR. The femoral intercondylar roof angle: radiographic and MRI measurement. *Am J Knee Surg*. 1993;6:10-14.
26. Staubli HU, Rauschning W. Tibial attachment area of the anterior cruciate ligament in the extended knee position: anatomy and cryosections in vitro complemented by magnetic resonance arthrography in vivo. *Knee Surg Sports Traumatol Arthrosc*. 1994;2(3):138-146.
27. Sward P, Kostogiannis I, Roos H. Risk factors for a contralateral anterior cruciate ligament injury. *Knee Surg Sports Traumatol Arthrosc*. 2010;18(3):277-291.
28. Zantop T, Wellmann M, Fu FH, Petersen W. Tunnel positioning of anteromedial and posterolateral bundles in anatomic anterior cruciate ligament reconstruction: anatomic and radiographic findings. *Am J Sports Med*. 2008;36(1):65-72.