Original Article

The Effect of Tibial Tunnel Drilling Technique on Retained Intra-Articular Bone Debris Following Anterior Cruciate Ligament Reconstruction

Lachlan Batty, M.B.B.S (Hons), F.R.A.C.S., Lachlan S. Huntington, B.Sci (Hons), M.D., Timothy Chung, M.B.B.S., Libby Spiers, BPhysio (Hons), Scott Tulloch, M.B.B.S. (Hons), F.R.A.C.S., Kate E. Webster, Ph.D., and Phong Tran, M.B.B.S., F.R.A.C.S.

Purpose: To assess the effect of tibial tunnel drilling technique (retro-drilled bone socket vs full tibial tunnel) on the presence and grade of postoperative, intra-articular bone debris following primary hamstring anterior cruciate ligament (ACL) reconstruction. **Methods:** This was a retrospective cohort study of primary hamstring autograft ACL reconstructions performed by 2 surgeons. Two blinded independent reviewers assessed the presence and length of retained intra-articular bone debris on the immediate postoperative lateral radiograph. Debris was graded according to a predefined 5-point ordinal grading system: grade 0 (no debris) to IV (severe debris). Results were analyzed according to the type of tibial tunnel; retro-drilled socket or full tibial tunnel using Kappa statistics and the Mann−Whitney *U* test. **Results:** Sixty-five patients undergoing primary hamstring ACL were included (39 tibial socket: 26 full tibial tunnel). Bone debris was observed among the tibial socket technique in 29 of 39 instances (74.3%), compared with 14 of 26 (53.8%) instances for the full tibial tunnel technique ($P = .09$). Where there was measurable debris present, the tibial socket group had a mean length of bone debris of 13.7 ± 6.2 mm as compared with the full tibial tunnel, 10.0 ± 4.7 mm ($P = .165$). There were significant differences in bone debris gradings between the 2 treatment groups, with tibial sockets having an overall greater grade ($P = .04$). **Conclusions:** A difference in the presence of, or length of, retained bone debris on the postoperative lateral radiograph was not demonstrated between the retro-drilled bone socket and full tibial tunnel techniques. However, when bone debris was present, greater grades of debris were seen in the retro-drilled socket group. **Level of Evidence:** III, retrospective, comparative study.

Remnant bone debris after anterior cruciate ligament (ACL) reconstruction has been reported on postoperative radiographs in 63% to 69% of cases.[1,2] Although the quality of evidence is low, it has been linked to postoperative complications such as persistent effusion[1] and early tunnel widening, potentially due to increased osteolytic enzymes within the knee to resorb the bone debris.[3] It also has been proposed as a risk factor for the development of arthrofibrosis[4,5] and for osteophyte development.[6] Importantly, techniques to reduce postoperative debris have been published, whereby rates were reduced to 15%.[2]

ACL reconstructive techniques continue to evolve. Traditional transtibial femoral tunnel drilling has transitioned to femoral tunnel drilling via the anteromedial portal[7] or outside-in femoral drilling techniques whereby the femoral tunnel is also typically drilled before the tibial tunnel. This potentially reduces the

From the Department of Orthopaedic Surgery, Western Health, Footscray Hospital, Melbourne (L.B., L.S.H., T.C., L.S., S.T., P.T.); School of Allied Health, Human Services and Sport, La Trobe University, Melbourne (L.B., K.E.W.); OrthoSport Victoria Research Unit, Epworth Hospital, Melbourne (L.B., P.T.); and Australian Institute for Musculoskeletal Science (AIMSS), The University of Melbourne and Victoria University, St. Albans (P.T.), Australia.

The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Lachlan Batty and Lachlan Huntington are co-first authors.

Received June 21, 2022; accepted December 1, 2022.

Address correspondence to Mr. Lachlan Batty, M.B.B.S (Hons), F.R.A.C.S., School of Allied Health, Human Services and Sport, Health Sciences 3 Building, La Trobe University, Melbourne, Victoria 3086, Australia. E-mail: Lachlan.batty@gmail.com

2666-061X/22771
https://doi.org/10.1016/j.asmr.2022.12.002

ability of bone debris to be flushed out of the knee during the femoral tunnel drilling process with egress of fluid and bone debris through the tibial tunnel. More recently, "all-inside" tibial bone tunnels have been popularized using incomplete bone "sockets" to dock grafts, rather than full-length, bicortical tunnels. This method has been associated with reduced postoperative pain,[8] the ability to use shorter and potentially larger-diameter hamstring grafts, and reduced tunnel widening while offering equivalent postoperative long-term outcomes to other techniques.[9] An incomplete tibial "socket," however, with a smaller tibial cortical diameter, results in a reduced channel size for arthroscopic fluid to flush through the tibial tunnel. This may further reduce the amount of bone debris that is flushed out of the joint with the flow of the arthroscopic fluid.

The purpose of this study was to assess the effect of tibial tunnel drilling technique (retro-drilled bone socket vs full tibial tunnel) on the presence of and grade of postoperative, intra-articular bone debris following primary hamstring ACL reconstruction. It was hypothesized that a retro-drilled tibial socket technique would result in greater rates and volumes of retained intra-articular bone debris due to reduced egress of bone debris being flushed out the smaller aperture tibial tunnel with the arthroscopic fluid.

Methods

Ethics approval for this study was obtained from an institutional review board at Western Health, Victoria, Australia. Project number QA2020.108 on December 18, 2020. As this was a retrospective study of existing standard of care collected data, patient consent was not required.

Patients and Study Setting

This study was a single-institution, retrospective review of patients undergoing primary hamstring autograft ACL reconstruction between January 1, 2017, and December 31, 2020, at a tertiary public hospital in Melbourne, Australia. A search of the institutional orthopaedic surgical database was performed to identify all patients who underwent an ACL reconstruction during this period. Clinical records were reviewed to assess for eligibility.

All patients undergoing primary ACL reconstruction using a hamstring autograft by 1 of 2 surgeons, S.T. and L.B., were included. The inclusion criteria were limited to these 2 surgeons, as they used an identical surgical technique during the study period, having performed multiple cases together. Each surgeon performed approximately 100 ACL reconstructions per year; however, many were at differing hospitals outside of the study institution. All patients required postoperative radiographs that included a horizontal beam lateral radiograph of the operative knee. Participants were excluded if they underwent ACL reconstruction with a non-hamstring graft. In addition, patients were excluded if they underwent meniscal root repair using bone tunnels, multiligamentous knee surgery, or had a concomitant fracture or notchplasty performed. Data extracted from the clinical record included age at time of ACL reconstruction, sex, the time elapsed from operation to radiograph, femoral and tibial fixation types and implants, tibial tunnel technique, tunnel diameter, the presence of concomitant meniscal injury and repair.

Surgical Technique

A single-bundle hamstring ACL reconstruction was performed under tourniquet control. The graft was fashioned with a quadrupled semitendinosus tendon set to 70 mm in length. If the graft diameter was under 7.5 mm for female patients or 8 mm for male patients, the gracillis tendon was harvested and doubled over the graft creating a 6-strand graft. Femoral fixation was with an adjustable-loop cortical suspensory button. Fluid management was with an automated fluid-management pump with pressure set to 40 mm Hg. This was occasionally increased 45 or 50 mm Hg intraoperatively to aid visualization if required. A 5.5-mm shaver and an electrocautery device were used to prepare the lateral wall and debride the tibial ACL stump. The femoral tunnel was drilled via the anteromedial portal with a low-profile reamer with the knee in hyperflexion. The reamer diameter corresponded to the graft size and a depth of 25 mm was drilled. Any visible intra-articular debris was routinely removed with the shaver when the knee was extended to 90° after the femoral tunnel was drilled. This included placing the shaver at the femoral tunnel entrance and in the posterolateral gutter to remove any excess bone debris from the femoral tunnel and joint, respectively. The tibial tunnel aimer was set to 55° and the aimer placed on the ACL tibial footprint. The only variation in surgical technique was tibial tunnel drilling and fixation. The tibial tunnel was drilled with either a cylindrical cannulated tibial reamer over wire to create a full tunnel or with a Flip Cutter (Arthrex, Naples, FL) to create a 30- to 35-mm retro-drilled socket. Tibial fixation was either with an ABS button (Arthrex) for the tibial socket technique or a TightRope Concave Attachable Button System (ABS; Arthrex) for the full tibial tunnel. The tibial technique evolved over the study period with both surgeons initially using a full tibial tunnel routinely. Both authors transitioned to the tibial socket technique by the end of the study period. If there was any concern regarding compromise of the tibial cortical bone by the retrodrill, the tunnel was converted to a full tibial tunnel and an ABS button was used for tibial sided fixation over the completed tibial tunnel as in the full tibial tunnel technique.

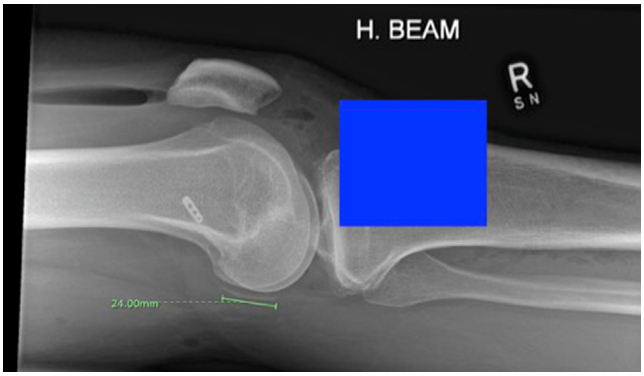

Fig 1. Lateral radiograph exhibiting severe (grade IV) bone debris (with exemplary length measurement (in millimeters) with tibial fixation blinding behind the superimposed blue square.

Radiograph Protocols

Radiographs were all performed at the same institution according to standard protocol. Patients would be discharged on the first postoperative day, with the radiographs taken before discharge. All patients followed the same physiotherapy institutional protocol immediately postoperatively and were encouraged to mobilize as soon as possible.

Radiographic Assessment

Radiographs were exported from the hospital picture archiving and communication system and imported into a PowerPoint file. This allowed blinding of the tibial tunnel technique, as shown in Figure 1. All radiographs were assessed independently by 2 reviewers (L.H. and T.C.) for the presence of, the length, and the grade of intra-articular bone debris on the lateral films, inferred from the maximum continuous length along the observed collection of debris (Table 1, Fig 2). If 2 discrete areas of debris were visible, then the 2 lengths were added. The density of debris and or the possibility that debris was overlapping was not assessed. Anteroposterior films were not used in the analysis, as a pilot study identified low sensitivity and poor intra- and interobserver reliability as the bone debris was commonly obscured by the tibial plateau or femoral condyles. This is consistent with previous studies investigating debris that have focused on only the lateral view for identification and analysis.[4,10] To assess intra- and interobserver reliability, the radiograph order in the PowerPoint file was scrambled before a repeat review 8 weeks later. In the case of disagreement, a third adjudicator (L.B.) was used to develop the final data set. The third reviewer was blinded to group and index reviewer assessments.

Statistical Analysis

The grade of bone debris was considered as nonparametric ordinal data, and the difference in grade between the tibial socket and full tunnel groups was assessed using the Mann—Whitney *U* test. Measurements of bone debris length were reported as means and standard deviations and between group differences were analyzed via the unpaired the Student *t*-test.[11] Intra- and interobserver reliability in detecting bone debris on the postoperative radiograph was assessed where Cohen kappa coefficients were calculated according to previously reported methods.[12,13] Kappa values were classified as described by Landis and Koch,[14] with values of 0.81 to 1.00 indicating excellent agreement, 0.61 to 0.80 substantial agreement, 0.41 to 0.60 moderate agreement, 0.21 to 0.40 fair agreement, and 0 to 0.20 slight agreement. Statistical significance was set at $P < .05$, and analysis was performed using SPSS statistical software (version 27; IBM Corp., Armonk, NY).

Results

A total of 371 patients underwent ACL reconstruction at the study institution across the reviewed period, of which 88 were performed by the study surgeons. Twenty-three were excluded, as they underwent multiple ligamentous reconstruction, bone—patella tendon—bone graft, or a notchplasty. Sixty-five patients were included (Table 2). Thirty-nine patients underwent ACL reconstruction with the tibial socket technique, whereas 26 underwent reconstruction with a full tibial tunnel (Table 2). A tear of the medial meniscus was present in 24 cases, with 11 undergoing repair. A tear of the lateral meniscus was present in 35 cases, with 10 undergoing repair. There were no cases of concomitant meniscal root repair requiring tunnel drilling. The mean time from surgery to radiograph was 20:48 (hours:minutes) ± 2:49 (standard deviation), range [14:57-27:06]. There was no difference between time to radiograph between groups (Table 2).

Inter- and Intraobserver Reliability of Bone Debris Grading

Intraobserver reliability for the grade of bone debris present on the radiographs indicated excellent

Table 1. Bone Debris Grading System for Postoperative Lateral Radiograph

Grade 0 — No debris
Grade I — Small elements or speckles of noncontinuous radiopaque bone debris, often only visible on magnified views (trace).
Grade II — Small line of continuous radiopaque bone debris measuring 0-10 mm in length (mild).
Grade III — Continuous line of radiopaque bone debris measuring 10-20 mm in length (moderate).
Grade IV — Significant line of continuous radiopaque bone debris measuring 20 or more mm in length and with increasing depth giving a crescentic appearance (severe).

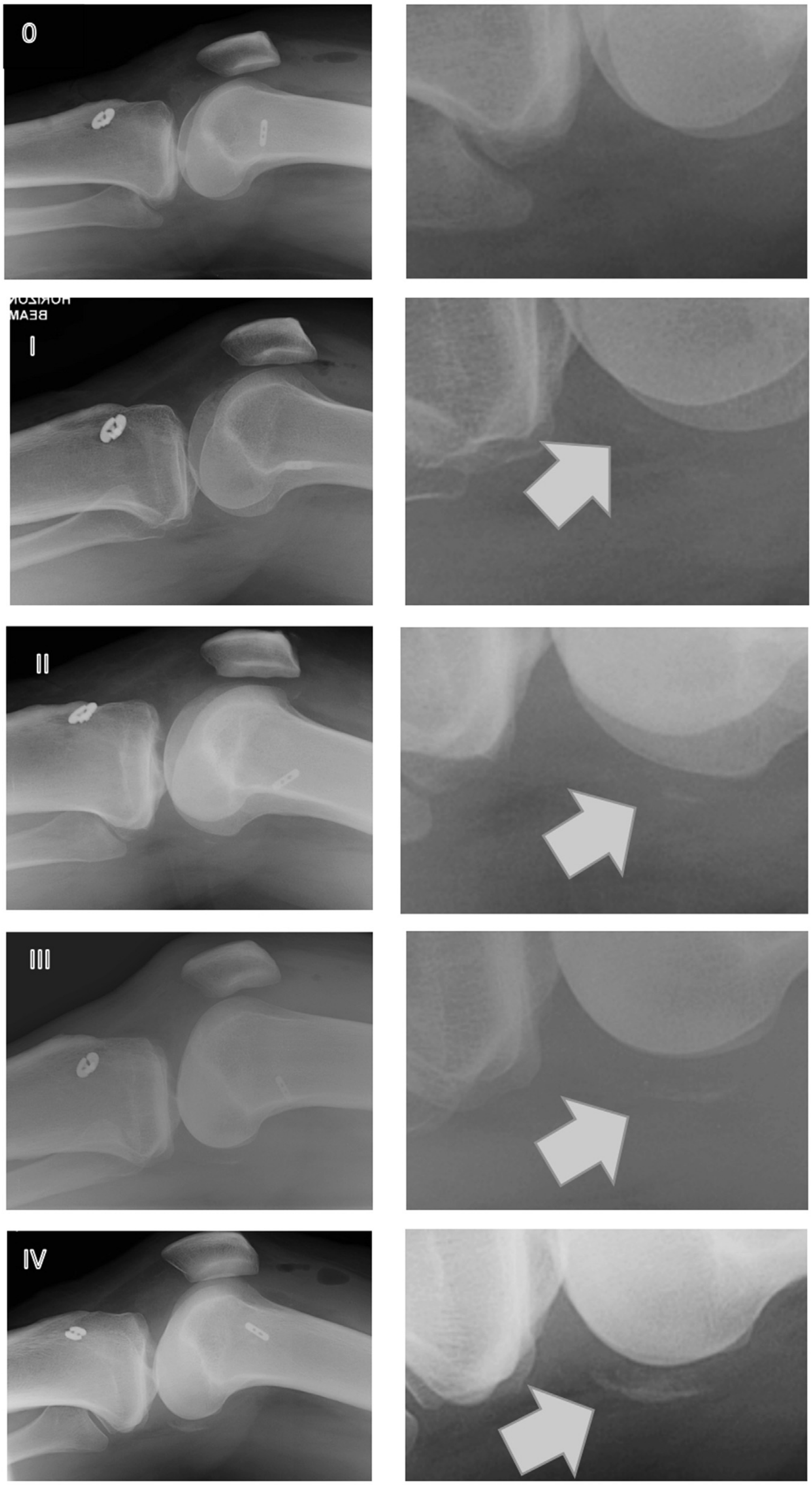

Fig 2. A diagram illustrating the authors proposed 5-point bone debris grading system, ranging from 0 (no debris) to IV (severe debris), according to measurable maximum length (in millimeters), for intra-articular debris on postoperative lateral plain radiographs of the knee. Left hand column exhibits the full radiograph, with the right-hand column exhibiting the magnified views of the posterior aspect of the knee joint.

agreement, with overall agreements of 76.9% and 86.2%, and weighted Cohens kappa values of 0.82 (reviewer 1) and 0.84 (reviewer 2). Interobserver reliability for the grading of bone debris indicated substantial agreement, with an overall agreement of 66.2%, and a Cohen weighted kappa value of 0.73.

Table 2. Patient Demographics

	Tibial Socket (n = 39)	Full Tibial Tunnel (n = 26)	*P* Value
Age, y	25.3 ± 6.2	25.7 ± 5.7	.97
Sex, male:female	25:14	18:8	.67
Operative side, left:right	18:21	16:10	.22
Tibial tunnel diameter, mm	8.5 ± 0.5	8.7 ± 0.9	.17
Femoral tunnel diameter, mm	8.4 ± 0.5	8.3 ± 0.9	.64
Time from operation to radiograph, h:min	20:48 ± 2:48	21:11 ± 2:59	.22

NOTE. Data presented as mean (standard deviation), unless otherwise indicated.

Effect of Tunnel Drilling Technique on Bone Debris Grading

Bone debris was observed among the tibial socket technique in 29 of 39 instances (74.3%), compared with 14 of 26 (53.8%) instances in the full tibial tunnel technique ($P = .09$, Table 3 and Fig 3). Where there was measurable bone debris, the full tibial tunnel group had a mean bone debris length of 10.0 ± 4.73 mm, whereas the tibial socket group was 13.7 ± 6.2 mm ($P = .165$). There was a significant between group difference for bone debris grading (Mann−Whitney U test $P = .04$, Table 3 and Fig 3), with tibial sockets observing a greater grade than full tibial tunnels. More patients from the full tibial tunnel technique group tended to have grade 0 or I debris, whereas more patients from the tibial socket technique group had grade III or IV debris.

Discussion

The most important finding of this study was that a difference in the presence of, or length of retained bone debris on the postoperative lateral radiograph was not demonstrated between the retro-drilled bone socket and full tibial tunnel techniques. However, when bone debris was present, greater grades of debris were seen in the retro-drilled socket group. Greater grades of retained bone debris may be an unanticipated sequelae of the recently popularized retro-drilling technique for the tibial tunnel.[15] While the presence of some bone debris was common in both techniques, the greater grade that was observed in the tibial socket patient cohort could be important if there is a dose−response relationship with any deleterious effects of retained bone debris. The difference in grading supports the hypothesis that with reduced fluid egress from a full tibial tunnel, there is a reduced opportunity for the bone debris to escape the joint.

Table 3. Distribution of Grade of Debris

	Grade of Debris					
Tunnel Type	0	I	II	III	IV	Total
Tibial socket	10	11	6	10	2	39
Full tibial tunnel	12	7	4	3	0	26

NOTE. Table represents the absolute number of cases identified within each grade of debris according to tibial tunnel type.

The clinical implications of residual bone debris after ACL reconstruction remain unclear. Wnorowski[1] found no negative outcomes associated with retained bone debris in 99 ACL-reconstructed knees with resolution of the debris by 6 months. There was no association with mechanical symptoms, KT-1000 laxity testing, or reoperation rates. There was, however, a trend toward greater rates and persistence of postoperative effusion seen in association with bone debris.[1] This was not statistically significant, but the study was likely underpowered for this outcome. The author acknowledged that the long-term effects were not considered. Of note, there was no assessment of patient-related outcome measures, tunnel widening, or of long-term osteoarthritis rates. Basso et al.[10] found no difference in the rates of postoperative effusion associated with retained debris in a series of 50 patients where 40 were found to have debris on the postoperative radiographs. Basso et al.[10] concluded that bone debris is unlikely associated with any early or late complication; however, the mean follow-up of this study was only 13.2 months. Others have conjectured that bone debris may be associated with the formation of osteophytes,[6] cyclops lesions,[5] or tunnel enlargement due to increased osteolytic enzymes within the knee to resorb the bone debris.

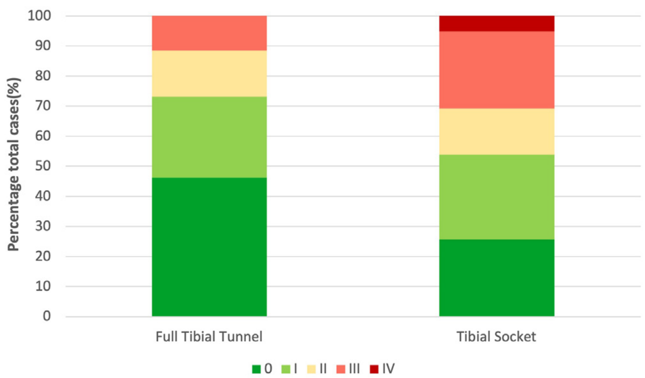

Fig 3. Relative proportion of grade of bone debris among total cases in the full tibial tunnel and tibial socket groups. Legend at the bottom chart denotes the color associated with each grade (0-IV).

Clearly, greater-quality evidence and long-term follow-up is required to fully understand the implications of bone debris following ACL reconstruction; however, all authors have advocated the removal of this debris where possible.[2] There is unlikely a potential benefit to retained debris; however, there is a possible harm and removal has very low or no morbidity.

There are a number of steps to minimize residual bone debris. First, awareness of this phenomenon is important, especially the association with retro drilling of tibial tunnels. Imam et al.[2] described a 5-point debris removal process that reduced the rate of retained debris from 69% to 15%. The 5 steps included debriding debris from the posteromedial compartment; debridement of the tibial tunnel before graft advancement; debridement of the femoral tunnel before graft advancement; debridement of the suprapatellar pouch; and debriding the donor site. MacDonald et al.[16] proposed a technique using a 20-mL syringe of sterile saline that is injected at high pressure at the femoral tunnel from outside to in to allow removal of bone debris. A similar technique to address bone debris in is now used at the study institution; however, at the time that included cases underwent reconstruction this was not routinely adopted. Immediately after the femoral tunnel is drilled, the authors now use the arthroscopic probe to pull out any residual bone from within the femoral tunnel and then use a large shaver to remove this. The shaver is placed at the tunnel entrance and through the notch to the posterior knee to collect any debris that has collected there. Removal of bone debris that clogs the shaver is often required. Inspection of the tibiofemoral joint spaces often shows debris in the region of the anterior horn of the medial and lateral meniscus. The knee is place into a varus, and subsequently valgus position to allow removal with the shaver from the lateral and medial compartments as well as a Gillquist maneuver as described by Imam et al.[2] Low suction on an additional superolateral outflow cannula may aid in fluid (and potentially bone) egress. Further, an additional outflow cannula or the shaver sheath placed into the knee via an accessory anteromedial portal at the time of femoral tunnel drilling is also effective, however, this requires an additional portal.

Limitations

This study has limitations. Accurate assessment of the presence and volume of bone debris is challenging. Computed tomography would allow 3-dimensional assessment of the volume of bone debris; however, this is not routine practice post ACL reconstruction. However, the proposed grading system observed substantial or excellent inter- and intraobserver reliability assessment scoring,[14] suggesting this method of classification is an acceptable way of quantifying severity. It is possible bone debris may accumulate in the back of the knee if the patient was recumbent for a longer period and then displace upon ambulation altering the radiographic appearance. This was not possible to control for, but no difference in the mean time from operation to radiograph between groups was observed, and there is no appreciable reason why one group would have ambulated more or less than the other group before the radiograph. To this point, other factors that may impact mobilization postoperatively, such as the use of peripheral nerve blocks, were not available within the hospital database. There was no difference in tunnel diameter between groups and with the consistent surgical technique. Femoral tunnel depths were presumed similar; however, these were not recorded. Patient numbers were too small to see whether addressing concomitant meniscal pathology had any effect on bone debris retention. Differing efforts to remove bone debris intraoperatively is another potential confounder; however, this study was conceptualized after all operations had been performed, and the surgeons were unaware that retained bone debris would be assessed. Both surgeons performed the same bone debris removal technique as previously described, and there is no reason to assume any systematic differences in the management of bone debris between groups. Retention of debris may reflect the learning curve associated with performing retro-drilled tibial sockets. Both surgeons were in a learning curve period for the adoption of the tibial socket technique. It is possible bone debris rates may reduce with increased experience and familiarity. Importantly, any surgeon adopting the technique should be conscious of the potential for increased debris retention and actively remove it when adopting the technique. Lastly, because of the retrospective nature of the study, underpowering may limit the strength of the conclusions.

Conclusions

A difference in the presence of, or length of, retained bone debris on the postoperative lateral radiograph was not demonstrated between the retro-drilled bone socket and full tibial tunnel techniques. However, when bone debris was present, greater grades of debris were seen in the retro-drilled socket group. Potential benefits of retro-drilling the tibial socket are not to be discounted; however, the authors recommend caution be applied with this technique in relation to retained intra articular bone debris.

References

1. Wnorowski DC. The fate of intra-articular debris following arthroscopic anterior cruciate ligament reconstruction. *Arthroscopy* 1997;13:620-626.
2. Imam MA, Abdelkafy A, Dinah F, Adhikari A. Does bone debris in anterior cruciate ligament reconstruction really

matter? A cohort study of a protocol for bone debris debridement. *SICOT J* 2015;1:4.

3. Ugutmen E, Ozkan K, Guven M, Sener N, Altintas F. Early tunnel enlargement after arthroscopic ACL reconstructions. *Acta Orthop Belg* 2007;73:625-629.
4. Delince P, Krallis P, Descamps PY, Fabeck L, Hardy D. Different aspects of the cyclops lesion following anterior cruciate ligament reconstruction: A multifactorial etiopathogenesis. *Arthroscopy* 1998;14:869-876.
5. Jackson DW, Schaefer RK. Cyclops syndrome: loss of extension following intra-articular anterior cruciate ligament reconstruction. *Arthroscopy* 1990;6:171-178.
6. Hart AJ, Buscombe J, Malone A, Dowd GS. Assessment of osteoarthritis after reconstruction of the anterior cruciate ligament: A study using single-photon emission computed tomography at ten years. *J Bone Joint Surg Br* 2005;87:1483-1487.
7. Mulcahey MK, David TS, Epstein DM, Alaia MJ, Montgomery KD. Transtibial versus anteromedial portal anterior cruciate ligament reconstruction using soft-tissue graft and expandable fixation. *Arthroscopy* 2014;30:1461-1467.
8. Lubowitz JH, Schwartzberg R, Smith P. Randomized controlled trial comparing all-inside anterior cruciate ligament reconstruction technique with anterior cruciate ligament reconstruction with a full tibial tunnel. *Arthroscopy* 2013;29:1195-1200.
9. Fu CW, Chen WC, Lu YC. Is all-inside with suspensory cortical button fixation a superior technique for anterior cruciate ligament reconstruction surgery? A systematic review and meta-analysis. *BMC Musculoskelet Disord* 2020;21:445.
10. Basso O, Johnson DP, Jewell F, Wakeley CJ. The outcome of intra-articular debris, following anterior cruciate ligament reconstruction. *Knee* 2001;8:235-237.
11. Dekker TJ, Schairer W, Grantham WJ, DePhillipo NN, Aman ZS, LaPrade RF. Isolated fibular collateral ligament reconstruction graft options in the setting of ACL reconstruction: Clinical and radiographic outcomes of autograft versus allograft. *Arthroscopy* 2021;37:944-950.
12. Karanicolas PJ, Bhandari M, Kreder H, et al. Evaluating agreement: Conducting a reliability study. *J Bone Joint Surg Am* 2009;91:99-106 (suppl 3).
13. Batty L, Murgier J, O'Sullivan R, Webster KE, Feller JA, Devitt BM. The Kaplan fibers of the iliotibial band can be identified on routine knee magnetic resonance imaging. *Am J Sports Med* 2019;47:2895-2903.
14. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;33:159-174.
15. Connaughton AJ, Geeslin AG, Uggen CW. All-inside ACL reconstruction: How does it compare to standard ACL reconstruction techniques? *J Orthop* 2017;14:241-246.
16. MacDonald DRW, Bruce E, Stevenson I. A novel technique for bone debris clearance during anterior cruciate ligament reconstruction. *J Arthrosc Joint Surg* 2019;6:131-132.