Patient Preferences for Graft Selection in Anterior Cruciate Ligament Reconstruction

Christian Pearsall,* MD, MS, Aaron Z. Chen,* MD, Abed Abdelaziz,* MD, Bryan M. Saltzman,†‡ MD, Dana P. Piasecki,†‡ MD, Charles A. Popkin,* MD, Lauren H. Redler,* MD, William N. Levine,* MD, Christopher S. Ahmad,* MD, and David P. Trofa,*§ MD

Investigation performed at the Department of Orthopedic Surgery, Columbia University Irving Medical Center, New York, New York, USA

Background: Selecting an appropriate graft for anterior cruciate ligament (ACL) reconstruction requires consideration of a patient's preferences, goals, age, and physical demands alongside the risks and benefits of each graft choice.

Purpose: To determine the most popular ACL reconstruction grafts among patients and the most important factors influencing their decisions.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: Patients undergoing ACL reconstruction between October 2022 and April 2023 completed a survey either before (nonconsult group) or after (consult group) speaking with their surgeon, who provided an evidence-based description of the pros and cons of an allograft and the following autografts: bone-patellar tendon-bone (BPTB), hamstring tendon (HT), and quadriceps tendon (QT). Patient characteristics, graft choice, information influencing their graft choice, and surgeon recommendation were collected and compared between the groups.

Results: Among the 100 included patients, 59.0% were male, and the mean age was 28.3 ± 10.4 years. The most popular grafts were the BPTB (56.0%), followed by the QT (29.0%), HT (8.0%), and allograft (7.0%). No significant difference was observed in the graft selection between the consult group (n = 60; BPTB, 46.7%; QT, 38.3%; HT, 8.3%; allograft, 6.7%) and nonconsult group (n = 40; BPTB, 70.0%; QT, 15.0%; HT, 7.5%; allograft, 7.5%) (P = .0757). In the consult group, 81.7% of patients selected the graft recommended to them by their surgeon. The top 2 graft selection reasons were usage in professional athletes and failure rates, while the top 2 ACL surgery concerns were returning to their desired level of athletics and graft failure risk. Among the 93 patients who researched their ACL graft options before their visit, the most popular information source was some form of media (72.0% [67/93]).

Conclusion: The study findings underscore the importance of patient preference and surgeon recommendation in a patient's graft selection and highlight the need to be cognizant of the information sources available to patients when researching their graft options.

Keywords: ACL reconstruction; graft; allograft; autograft

Anterior cruciate ligament (ACL) reconstruction is one of the most common surgical procedures in orthopaedics, occurring 100,000 to 200,000 times per year in the United States.[11,14,17,24,31] Despite its ubiquity, graft choice in ACL reconstruction remains a contentious topic.[7,11,16,17] Grafts used for ACL reconstruction have different risk-benefit profiles and include the bone-patellar tendon-bone (BPTB) autograft, hamstring tendon (HT) autograft, and quadriceps tendon (QT) autograft as well as a number of various allograft options.[5,11,33,40] The BPTB graft has long been considered the gold standard for athletes because of its fast incorporation times and low failure rates; however, downsides include donor site morbidity such as anterior knee pain.[1,5,7,8,10,13] Compared to BPTB

The Orthopaedic Journal of Sports Medicine, 12(8), 23259671241258429
DOI: 10.1177/23259671241258429
© The Author(s) 2024

This open-access article is published and distributed under the Creative Commons Attribution - NonCommercial - No Derivatives License (https://creativecommons.org/licenses/by-nc-nd/4.0/), which permits the noncommercial use, distribution, and reproduction of the article in any medium, provided the original author and source are credited. You may not alter, transform, or build upon this article without the permission of the Author(s). For article reuse guidelines, please visit SAGE's website at http://www.sagepub.com/journals-permissions.

grafts, HT grafts may have delayed incorporation times and higher failure rates, but they have reduced donor site morbidity.[1,5,7,8,10,13,38] The QT autograft is a newer option with promising results to suggest satisfactory outcomes with minimal drawbacks, but it is significantly understudied compared to the other autograft options, and it lacks robust long-term data.[16,27,34,35] Compared to autografts, allografts offer reduced donor site morbidity and shorter operative times; however, they are prone to failure in younger adults and have delayed incorporation times.[21,39]

Selecting an appropriate graft for ACL reconstruction amid the various options requires consideration of a patient's preferences, goals, age, and physical demands alongside the risks and benefits of each graft choice. Therefore, educating and tailoring preoperative discussions with patients in accordance with their needs and concerns require understanding relevant patient-related factors that may influence their decision.[5,7] Although previous evidence has suggested the importance of both patient and surgeon preferences on a patient's ACL graft selection, no published survey-based reports have evaluated both patient and surgeon selection behaviors across the different autograft options, including the newer QT graft, before surgery.[8,9,17,21,30,33,36]

The aim of this study was to determine patient preferences of several ACL graft options at a single center with and without surgeon influence and understand the important factors driving these preferences. We hypothesized that both patient preference and their surgeon's recommendation would be important factors in a patient's graft selection.

METHODS

Study Patients

The study protocol was approved by the institutional review board of our university. Inclusion criteria were all patients aged 10 to 65 years who underwent ACL reconstruction with 1 of 5 fellowship-trained sports medicine surgeons (C.P., L.H.R., W.N.L., C.S.A., and D.P.T.) between October 2022 and April 2023 at our tertiary referral center. Exclusion criteria were patients who either did not respond to our survey and those who did not complete the entire survey.

All patients who completed the survey visited one of the participating orthopaedic attending surgeons in the clinic as a new patient, were diagnosed with an ACL tear, and ultimately consented to undergo ACL reconstruction. For patients diagnosed with an ACL tear, each surgeon exclusively asked them to participate in the survey either before (nonconsult group) or after (consult group) graft options were discussed. Patients in the nonconsult group were immediately emailed the survey to complete during their clinic visit before the discussion of graft options, with the attending surgeon stepping out of the room while patients completed the survey. Patients in the consult group were informed by their surgeon that they would be sent the survey to complete via email at some point after their clinic visit. The clinic notes of the patients in the consult group were examined to identify those who were indicated for ACL reconstruction, and the survey was sent to these patients via the email address listed in their electronic medical record.

Therefore, while all patients in the present study were diagnosed with an ACL tear during their clinic visit with one of the participating attending surgeons, they were identified either in the clinic at the time of the diagnosis (nonconsult group) or via a review of the electronic medical record of the clinic notes (consult group), depending on the specific surgeon. The email sent to patients briefly described the study's purpose, requested their participation, and contained a link to the survey itself if patients consented to participate. Patients were provided the option to opt out of participation when they were contacted regarding this study. Because patients in the consult group spoke with their surgeon and received a graft recommendation before completing the survey, they were aware of their surgeon's graft preference.

Study Survey

The survey, which was created via the experience management software Qualtrics XM (Silver Lake Technology Management, L.L.C.), provided background information and an evidence-based description of the pros and cons of available ACL graft options (BPTB, HT, QT, and allograft). All survey questions are included in Appendix Table A1, and an evidence-based description of the different graft options is included in Appendix Table A2. A separate database was created to track all emails sent to patients, whether patients responded to the survey, and how much of the

[§]Address correspondence to David P. Trofa, MD, Department of Orthopedic Surgery, Columbia University Irving Medical Center, 161 Fort Washington Avenue, New York, NY 10032, USA (email: dpt2103@cumc.columbia.edu).

*Department of Orthopedic Surgery, Columbia University Irving Medical Center, New York, New York, USA.

[†]OrthoCarolina Sports Medicine Center, Charlotte, North Carolina, USA.

[‡]Atrium Health Musculoskeletal Institute, Charlotte, North Carolina, USA.

Final revision submitted March 21, 2024; accepted April 26, 2024.

One or more of the authors has declared the following potential conflict of interest or source of funding: B.M.S. has received education payments from Arthrex and Smith+Nephew and consulting fees from Bioventus. D.P.P. has received education payments from Arthrex and consulting fees from Zimmer Biomet. L.H.R. has received education payments from Gotham Surgical and honoraria from AcelRx Pharmaceuticals. W.N.L. has received education payments from Gotham Surgical, consulting fees from Zimmer Biomet, and royalties from Zimmer Biomet. C.S.A. has received nonconsulting fees and royalties from Arthrex. D.P.T. has received education payments from Arthrex and Smith+Nephew. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval for this study was obtained from Columbia University (ref No. AAAS9234(M00Y03)).

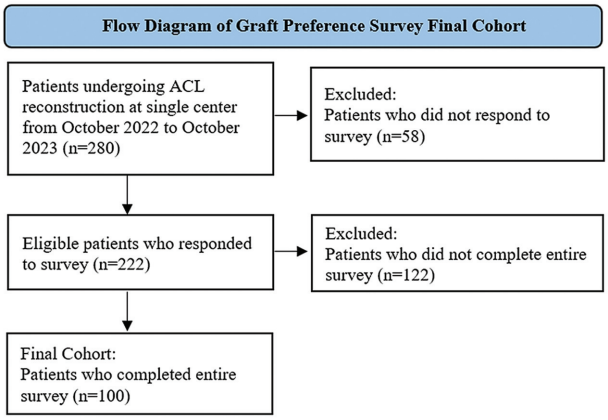

Figure 1. CONSORT (Consolidated Standards of Reporting Trials) flowchart of the patient inclusion and exclusion process.

survey had been completed. Patients who did not respond to the survey were resent the original email at 1-week intervals up to a total of 3 times. The survey was reviewed by a fellowship-trained sports medicine surgeon to verify its accuracy (D.P.T.).

The survey also contained questions related to patient characteristics, prior sources of information pertaining to graft options (eg, a prior Internet search or family member), treating surgeon's graft recommendation (if applicable), final patient graft preference, and the most influential factor in their graft choice. Patients were also asked to rank the importance of the 5 following concerns regarding their ACL surgery from 1 (most important concern) to 5 (least important concern): length of surgery, possibility of an ACL rerupture, other complications unrelated to a rerupture (knee stiffness, knee pain, infection), surgical incision length, and ability to return to their desired level of athletics.

Statistical Analysis

Statistical analysis was performed with Excel (Microsoft; Version 2405). Continuous variables were reported as means with standard deviations and ranges where appropriate. Categorical variables were reported as frequencies and percentages and compared with the chi-square test or the Fisher exact test when applicable. Ultimately, 2-sided P values $<.05$ were considered statistically significant.

RESULTS

Of 280 patients undergoing ACL reconstruction who were identified and sent the graft preference survey via electronic mail, 222 patients responded to the survey. Notably, 122 patients' responses were incomplete and therefore excluded, leaving a final cohort of 100 patients with complete survey responses (Figure 1).

TABLE 1
Baseline Characteristics of Patients (n = 100)[a]

	Value
Age, y	28.3 ± 10.4
Male sex, %	59.0
College degree or higher, %	47.0
Different sports played by cohort, n	28
No. of sports played by each patient	3.2 ± 2.3
Time playing primary sport, mo	9.5 ± 3.2
Top 3 sports, %	
Running	32.0
Basketball	31.0
Skiing	30.0
Injuries that occurred during sports, %	70.0

[a]Data are reported as mean ± SD unless otherwise indicated.

TABLE 2
Graft Selection[a]

	Overall (n = 100)	Consult Group (n = 60)	Nonconsult Group (n = 40)
Bone-patellar tendon-bone	56 (56.0)	28 (46.7)	28 (70.0)
Quadriceps tendon	29 (29.0)	23 (38.3)	6 (15.0)
Hamstring tendon	8 (8.0)	5 (8.3)	3 (7.5)
Allograft	7 (7.0)	4 (6.7)	3 (7.5)

[a]Data are reported as n (%). No significant difference was observed in the graft selection between the consult and nonconsult groups (P = .0757 [chi-square test]).

Baseline characteristics of the final cohort are displayed in Table 1. The mean patient age was 28.3 ± 10.4 years, and 59.0% of respondents were male. Respondents played a mean number of 3.2 ± 2.3 sports, with the most popular ones being running, basketball, and skiing. Injuries occurred during sports in 70.0% of participants.

The consult group consisted of 60 patients, and the nonconsult group consisted of 40 patients. The graft selection percentages for the entire cohort are shown in Table 2. Among the entire cohort, the most popular graft selected was the BPTB graft (56.0% [56/100]), followed by the QT graft (29.0% [29/100]), HT graft (8.0% [8/100]), and allograft (7.0% [7/100]). In the consult group, the most popular graft was the BPTB graft (46.7% [28/60]), followed by the QT graft (38.3% [23/60]), HT graft (8.3% [5/60]), and allograft (6.7% [4/60]). In the nonconsult group, the BPTB graft was most often selected (70.0% [28/40]), followed by the QT graft (15.0% [6/40]), HT graft (7.5% [3/40]), and allograft (7.5% [3/40]). There was no significant difference observed in the graft selection between the consult group and the nonconsult group (P = .0757).

The graft selection of patients, surgeon's graft recommendation, and percentage of surgeon recommendations that matched the patient's graft selection in the consult group are shown in Figure 2. The BPTB graft was the most recommended graft by surgeons (45.0% [27/60]),

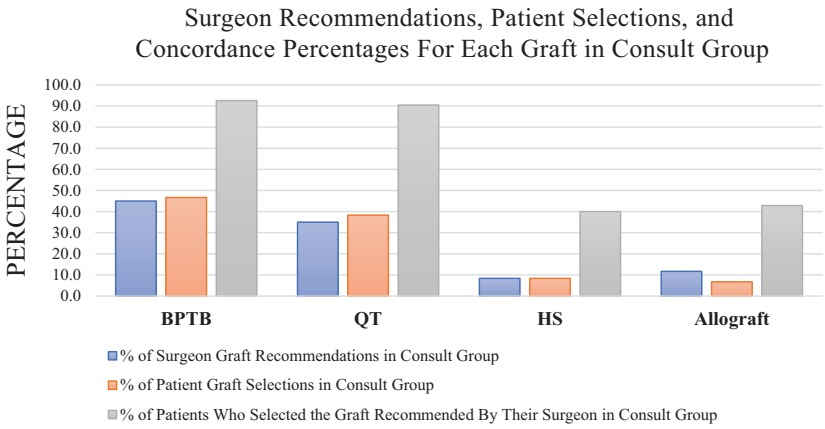

Figure 2. Graft recommendation, selection, and concordance in the consult group (n = 60). BPTB, bone-patellar tendon-bone; HT, hamstring tendon, QT, quadriceps tendon.

TABLE 3
Factors Influencing Prior Knowledge of Graft Options and Graft Selection

	n (%)
Sources used in prior research of graft options (n = 93)	
Media, including the Internet or news source	67 (72.0)
Physician recommendation	51 (54.8)
Family member or friends	38 (40.9)
Athletic trainer or coach	29 (31.2)
Most important reason for graft selection (n = 100)	
Graft usage in professional athletes	24 (24.0)
Reported failure rates	23 (23.0)
Prior surgeon recommendation	18 (18.0)
No influence	11 (11.0)
Postoperative knee pain	10 (10.0)
Other reason not listed	5 (5.0)
Other complications such as knee stiffness or infection	4 (4.0)
Family's or friend's input	3 (3.0)
Athletic trainer's or coach's input	2 (2.0)

followed by the QT graft (35.0% [21/60]), allograft (11.7% [7/60]), and HT graft (8.3% [5/60]). Patients selected the graft that was recommended to them by their surgeon 92.6% (25/27) of the time for the BPTB graft, 90.5% (19/21) for the QT graft, 42.9% (3/7) for the allograft, and 40.0% (2/5) for the HT graft. Patients who did not select their surgeon's recommended graft selected the allograft (n = 1) and QT graft (n = 1) instead of the BPTB graft; the HT graft (n = 2) instead of the QT graft; the HT graft (n = 2), QT graft (n = 1), and BPTB graft (n = 1) instead of the allograft; and the BPTB graft (n = 2) and QT graft (n = 1) instead of the HT graft. Notably, among the consult group, there was no significant difference between grafts recommended by surgeons versus grafts selected by patients (P = .819).

Table 3 illustrates all sources of information utilized by those who independently researched ACL graft options before completing the survey and the most important factors that influenced each participant's graft selection. Among the overall cohort, 93.0% (93/100) of participants reported independently researching ACL graft options with ≥1 of the following sources. Arranged from most to least frequently queried, they are as follows: media, including the Internet or news source (72.0% [67/93]), followed by physician recommendation (54.8% [51/93]), family member or friend (40.9% [38/93]), and athletic trainer or coach (31.2% [29/93]). When asked to provide the single most important factor that influenced their graft choice, the 3 most popular reasons were graft usage in professional athletes (24.0% [24/100]), reported failure rates (23.0% [23/100]), and prior surgeon recommendation (18.0% [18/100]).

Expressed as a dimensionless mean rank on a scale from 1 (most important) to 5 (least important), the overall most important patient-reported surgical concern was the ability to return to their desired level of athletics (1.8 ± 1.1), followed by the possibility of an ACL rerupture (2.4 ± 1.1), other complications unrelated to a rerupture (knee stiffness, knee pain, infection; 2.8 ± 1.0), the length of surgery (3.8 ± 1.3), and the surgical incision length (4.3 ± 0.9).

DISCUSSION

Although understanding patient preferences in ACL graft selection is critical in helping physicians tailor their discussions of graft options to fit each patient's needs, only 5 studies have surveyed patient perceptions in this context.[8,9,21,30,36] To our knowledge, the current study is the only survey-driven study to evaluate patient graft preferences and selection among 4 graft options, including the newer QT graft. Notably, the 2 most popular patient choices were BPTB (56.0%) and QT (29.0%) grafts, and 81.7% of patients selected the graft recommended to them by their surgeon. Moreover, the top 2 patient concerns about surgery were the ability to return to activity levels and the risk of ruptures, while the top 2 reasons for graft selection were graft usage by professional athletes and rupture rates. Because these patient-reported factors are most

consistent with the strengths of the 2 most popular grafts selected (BPTB and QT), the results of the present study strongly suggest that both patient preference and surgeon recommendation played an important role in graft choice.

Our finding that the BPTB graft was the most popular graft (56.0%) among a cohort of patients who reported playing a mean of 3.2 ± 2.3 sports is consistent with other survey-based reports and previous literature demonstrating its widespread use, especially among athletes.[5-7,11,32,40] The popularity of the BPTB graft could be explained by its quicker healing time compared with soft tissue grafts and rigid fixation with excellent stability, which translates to low graft failure rates at 2 years (1.5%-5.5%) and high return-to-sports rates (70%-84%).[‖] However, disadvantages of the BPTB graft include an increased risk of osteoarthritis and several donor site complications including anterior knee pain, infrasaphenous nerve injuries, patellar fractures, and extensor mechanism abnormalities, which might dissuade patients from selecting it.[¶] Nevertheless, in a survey-based study that provided patients with HT and BPTB graft outcome data, Sonnier et al[36] found that 64% of participants favored the BPTB graft over the HT autograft. Similarly, a retrospective survey report of 240 patients undergoing ACL reconstruction found the BPTB graft to represent 83.3% of all autografts selected.[9] A survey report by Cheung et al[8] found that only 10% of patients selected BPTB autografts among 159 ACL reconstruction cases, although only 17.3% of respondents were college-level athletes or higher. Similarly, among 304 ACL reconstruction cases, a survey-based report by Salminen et al[30] found that only 47% of patients received autografts, although the survey omitted each patient's level of athletic participation.

Among patients in the consult group, 92.6% and 90.5% of patients selected BPTB and QT grafts, respectively, when their surgeon recommended it, suggesting the important influence of surgeon recommendation in a patient's graft selection. Moreover, no significant difference was observed between the surgeon's graft recommendation and the consult group's graft selection ($P = .819$), and surgeon recommendation was the third most popular patient-reported reason for graft selection. These findings are consistent with the 4 survey reports that found surgeon recommendation to be the most important factor in graft selection, and they are also supported by a report from the The Multicenter Orthopaedic Outcomes Network (MOON) Knee Group, which found surgeon preference to be the most important variable in autograft selection among high school athletes.[8,9,21,30,37] Although the only survey-based study to report data on QT autografts found that they represented only 1% of the autografts used in that study, the results of the present study found the QT graft to be the second most popular graft (29.0%), with greater selection among those with prior surgeon consultations (38.3%) compared to those without (15.0%).[9] The high popularity of the QT graft may be explained by its advantages of having a large cross-sectional area; comparable biomechanical strength to the BPTB graft; and lower risk of anterior knee pain, patellar tendon damage, and infrasaphenous nerve damage compared to the BPTB graft.[5,7,27,35] Although QT autografts have promising return-to-sports rates as high as 86%, low failure rates from 1.4% to 4% at 2 years, and functional outcome scores similar to BPTB grafts, these results must be interpreted with caution, as these grafts lack robust long-term evidence demonstrating their effectiveness.[5,7,16,27,35] Nevertheless, the QT graft may be a suitable option for young athletes who kneel and use their hamstring, including those who are not skeletally mature.[5,7]

The present survey found the HT graft to be the least popular autograft option (8.0%), and only 40.0% of patients who were recommended this graft by their surgeon selected it. These results are consistent with findings by Cohen et al,[9] who reported that only 5.5% of survey respondents received an HT autograft, and findings by Sonnier et al,[36] who reported that only 36.5% of respondents preferred the HT graft over the BPTB autograft. The low popularity of the HT graft in these surveys could be caused by well-documented concerns of graft failure, reported as high as 17.5%, and prolonged graft integration times of up to 12 weeks.[5,7,16] Nevertheless, the HT graft, which is one of the most highly studied ACL graft options, offers high tensile strength, has demonstrated satisfactory patient-reported outcome scores and return-to-sports rates of up to 70%, and has reduced donor site morbidity compared to the BPTB graft.[4,5,7,16,28] The HT graft is therefore a reasonable option in patients, regardless of their skeletal maturity, who do not have significant athletic demands and who do not rely on hamstring strength extensively.[5,7,33] Indeed, these advantages may explain why the HT graft was the highest selected autograft in both the survey-based studies of Salminen et al[30] (64%) and Cheung et al[8] (82%).

Our rates showing the low popularity of allografts for patient selection (7.0%) and surgeon recommendation (11.7%) were lower compared to other survey-based reports and could be caused by their higher cost than autografts, high failure rates of up to 25% in young patients, and low return-to-sport rates of less than 50% in young patients.[5,8,9,18,20,21,30,39] Nevertheless, the increased popularity of allografts in other reports may be caused by their advantages, including shorter operative times, reduced donor site morbidity, and predictable graft sizes; they may also be preferred in older or lower demand patients, those with multiligamentous injuries, and patients with insufficient autograft tissue.[5,7,33] The 49% of respondents selecting an allograft in a report by Koh et al[21] cited unlimited graft sizes, shorter operative times, and reduced donor site morbidity as important reasons in their decision, while the most important factor among the 64% of respondents who selected an allograft in the survey by Cohen et al[9] was reduced donor site morbidity. Cheung et al[8] concluded that the high popularity of allografts selected (43%) was largely influenced by concerns over donor site morbidity, as reported by 30.5% of survey respondents. Similarly, while the survey by Salminen et al[30] did not investigate many graft-specific reasons for selection, they found that 39% of patients selected an allograft.

[‖]References 5-7, 10, 16, 19, 23, 29, 32, 33, 41.
[¶]References 2-5, 7, 13, 22, 25, 26, 28, 33, 40, 41.

Previous studies have strongly suggested that a patient's selection depends on which graft characteristics are most important to them.[8,9,21] Indeed, Koh et al[21] found the use of autologous tissue and graft incorporation rates to be among the top reasons for autograft selection and lower donor site morbidity and shorter operative times to be among the top reasons for allograft selection. Sonnier et al[36] found patients selecting BPTB grafts to prioritize return-to-sports and failure rates while those who selected HT grafts to prioritize complication rates. The results of the present study found the top 2 patient-reported concerns about surgery to be return to preinjury levels and graft rupture risk, while the top 2 most influential reasons for graft selection among patients were usage in professional athletes and graft rupture rates. Therefore, our results are consistent with these previous reports, as the 2 most popular patient-reported considerations, broadly described as postoperative functional status and graft failure risk, were consistent with the strengths of the 2 most popular grafts selected by patients (BPTB and QT autografts).

The present study found that 93.0% of survey respondents reported having prior knowledge of ACL graft options before their visit and that the most reported information source (72.0%) was media, including the Internet and news. These findings are consistent with the survey-based data from Koh et al,[21] who found 80.6% of survey respondents to have reported consulting the Internet before their visit. In the survey study by Cheung et al,[8] 51.7% of respondents reported conducting significant research on graft options, with most (41.1%) citing the Internet as their source of information. Although Cohen et al[9] found that 7% of patients cited the Internet as integral to their graft choice and Salminen et al[30] found that 13% of patients reported media as an important consideration in their graft choice, neither study described the proportion of patients who independently researched their graft options before their visit. These findings underscore the importance of being aware of the online and often unregulated sources that patients may solicit when researching their graft options to clarify potentially misleading or incomplete information that may have otherwise influenced their preferences and beliefs.[12,15]

Strengths and Limitations

The strengths of this study are that it is the only current survey-based study to evaluate patient preferences among the 4 graft options, including the newer QT graft, before surgery. Moreover, most survey-based studies merely assess the importance of surgeon recommendation via patient questionnaires rather than having both patients and surgeons select grafts. Therefore, including both of their choices for a direct comparison is another strength. Finally, polling the patients for their chief concerns, reasons for graft selection, and potential sources of prior graft knowledge yielded critical insights into what might drive patient preferences in graft selection.

The limitations of this study include the low response rate (35.7%) and the fact that the surveys were all conducted at a single center, both of which are potential sources of bias. Although the sample size of 100 is within the range of other survey-based studies, it is a small sample size when considering that the distribution of 4 grafts was analyzed. Because each attending surgeon exclusively discussed graft options either before or after the completion of the survey, placement into the consult and nonconsult groups was dependent on each patient's selection of an orthopaedic surgeon, which is nonrandom and may introduce bias. Another limitation is that the survey did not ask patients if they discussed graft options with a previous provider because the impact of surgeon preference on patient graft selection in the present study suggests that the preferences of previous providers could have influenced patient graft selection in the present study's survey. The data presented to the patients in the survey are based on a selected group of studies and are therefore subject to publication bias. Patients in the present study had a high mean age (28.3 $\pm$ 10.4 years) and participated in a mean of 3.2 $\pm$ 2.3 different sports, which may have biased their graft choices and may not be generalizable. Finally, the use of 1 category representing allografts rather than providing the different types of allografts that could be used also introduces bias.

CONCLUSION

As the only survey-based study to evaluate both patient and surgeon preferences of all graft options before surgery, the results demonstrate that the popularity of the BPTB and QT grafts was likely driven by both patient preference, which reflected the strengths of these grafts, and surgeon recommendation, which patients usually followed. In addition to underscoring the importance of individualizing discussions of a patient's graft options, the results also illustrate the role of media in influencing patient knowledge about graft options, suggesting value in being aware of sources that patients may cite from their independent research.

REFERENCES

1. Ajrawat P, Dwyer T, Whelan D, et al. A comparison of quadriceps tendon autograft with bone-patellar tendon-bone autograft and hamstring tendon autograft for primary anterior cruciate ligament reconstruction: a systematic review and quantitative synthesis. *Clin J Sport Med*. 2021;31(4):392-399.
2. Allum R. Complications of arthroscopic reconstruction of the anterior cruciate ligament. *J Bone Joint Surg Br*. 2003;85(1):12-16.
3. Almekinders LC, Moore T, Freedman D, Taft TN. Post-operative problems following anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 1995;3(2):78-82.
4. Björnsson H, Samuelsson K, Sundemo D, et al. A randomized controlled trial with mean 16-year follow-up comparing hamstring and patellar tendon autografts in anterior cruciate ligament reconstruction. *Am J Sports Med*. 2016;44(9):2304-2313.
5. Buerba RA, Boden SA, Lesniak B. Graft selection in contemporary anterior cruciate ligament reconstruction. *J Am Acad Orthop Surg Glob Res Rev*. 2021;5(10):e21.00230.
6. Cain EL, Clancy WG. Anatomic endoscopic anterior cruciate ligament reconstruction with patella tendon autograft. *Orthop Clin North Am*. 2002;33(4):717-725.

7. Cerulli G, Placella G, Sebastiani E, Tei MM, Speziali A, Manfreda F. ACL reconstruction: choosing the graft. *Joints*. 2013;1(1):18-24.
8. Cheung SC, Allen CR, Gallo RA, Ma CB, Feeley BT. Patients' attitudes and factors in their selection of grafts for anterior cruciate ligament reconstruction. *Knee*. 2012;19(1):49-54.
9. Cohen SB, Yucha DT, Ciccotti MC, Goldstein DT, Ciccotti MA, Ciccotti MG. Factors affecting patient selection of graft type in anterior cruciate ligament reconstruction. *Arthroscopy*. 2009;25(9):1006-1010.
10. DeFazio MW, Curry EJ, Gustin MJ, et al. Return to sport after ACL reconstruction with a BPTB versus hamstring tendon autograft: a systematic review and meta-analysis. *Orthop J Sports Med*. 2020;8(12):2325967120964919.
11. Duchman KR, Lynch TS, Spindler KP. Graft selection in anterior cruciate ligament surgery: who gets what and why? *Clin Sports Med*. 2017;36(1):25-33.
12. Duncan IC, Kane PW, Lawson KA, Cohen SB, Ciccotti MG, Dodson CC. Evaluation of information available on the Internet regarding anterior cruciate ligament reconstruction. *Arthroscopy*. 2013;29(6):1101-1107.
13. Freedman KB, D'Amato MJ, Nedeff DD, Kaz A, Bach BR. Arthroscopic anterior cruciate ligament reconstruction: a metaanalysis comparing patellar tendon and hamstring tendon autografts. *Am J Sports Med*. 2003;31(1):2-11.
14. Gottlob CA, Baker CL, Pellissier JM, Colvin L. Cost effectiveness of anterior cruciate ligament reconstruction in young adults. *Clin Orthop Relat Res*. 1999;367(367):272-282.
15. Guzman AJ, Dela Rueda T, Williams N, et al. Online patient education resources for anterior cruciate ligament reconstruction: an assessment of the accuracy and reliability of information on the Internet over the past decade. *Cureus*. 2023;15(10):e46599.
16. Haybäck G, Raas C, Rosenberger R. Failure rates of common grafts used in ACL reconstructions: a systematic review of studies published in the last decade. *Arch Orthop Trauma Surg*. 2022;142(11):3293-3299.
17. Hofbauer M, Muller B, Murawski CD, van Eck CF, Fu FH. The concept of individualized anatomic anterior cruciate ligament (ACL) reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2014;22(5):979-986.
18. Kaeding CC, Pedroza AD, Reinke EK, et al. Change in anterior cruciate ligament graft choice and outcomes over time. *Arthroscopy*. 2017;33(11):2007-2014.
19. Kaeding CC, Pedroza AD, Reinke EK, et al. Risk factors and predictors of subsequent ACL injury in either knee after ACL reconstruction: prospective analysis of 2488 primary ACL reconstructions from the MOON cohort. *Am J Sports Med*. 2015;43(7):1583-1590.
20. Keizer MNJ, Hoogeslag RAG, van Raay JJAM, Otten E, Brouwer RW. Superior return to sports rate after patellar tendon autograft over patellar tendon allograft in revision anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2018;26(2):574-581.
21. Koh HS, In Y, Kong CG, Won HY, Kim KH, Lee JH. Factors affecting patients' graft choice in anterior cruciate ligament reconstruction. *Clin Orthop Surg*. 2010;2(2):69-75.
22. Lin KM, Boyle C, Marom N, Marx RG. Graft selection in anterior cruciate ligament reconstruction. *Sports Med Arthrosc Rev*. 2020;28(2):41-48.
23. Lind M, Strauss MJ, Nielsen T, Engebretsen L. Quadriceps tendon autograft for anterior cruciate ligament reconstruction is associated with high revision rates: results from the Danish Knee Ligament Registry. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(7):2163-2169.
24. Lohmander LS, Englund PM, Dahl LL, Roos EM. The long-term consequence of anterior cruciate ligament and meniscus injuries: osteoarthritis. *Am J Sports Med*. 2007;35(10):1756-1769.
25. Marder RA, Raskind JR, Carroll M. Prospective evaluation of arthroscopically assisted anterior cruciate ligament reconstruction: patellar tendon versus semitendinosus and gracilis tendons. *Am J Sports Med*. 1991;19(5):478-484.
26. Mohtadi NGH, Chan DS, Dainty KN, Whelan DB. Patellar tendon versus hamstring tendon autograft for anterior cruciate ligament rupture in adults. *Cochrane Database Syst Rev*. 2011;2011(9):CD005960.
27. Mouarbes D, Menetrey J, Marot V, Courtot L, Berard E, Cavaignac E. Anterior cruciate ligament reconstruction: a systematic review and meta-analysis of outcomes for quadriceps tendon autograft versus bone-patellar tendon-bone and hamstring-tendon autografts. *Am J Sports Med*. 2019;47(14):3531-3540.
28. Pinczewski LA, Lyman J, Salmon LJ, Russell VJ, Roe J, Linklater J. A 10-year comparison of anterior cruciate ligament reconstructions with hamstring tendon and patellar tendon autograft: a controlled, prospective trial. *Am J Sports Med*. 2007;35(4):564-574.
29. Rousseau R, Labruyere C, Kajetanek C, Deschamps O, Makridis KG, Djian P. Complications after anterior cruciate ligament reconstruction and their relation to the type of graft: a prospective study of 958 cases. *Am J Sports Med*. 2019;47(11):2543-2549.
30. Salminen M, Kraeutler M, Freedman K, et al. Choosing a graft for anterior cruciate ligament reconstruction: surgeon influence reigns supreme. *Am J Orthop (Belle Mead NJ)*. 2016;45(4):192-197.
31. Sanders TL, Maradit Kremers H, Bryan AJ, et al. Incidence of anterior cruciate ligament tears and reconstruction: a 21-year population-based study. *Am J Sports Med*. 2016;44(6):1502-1507.
32. Schoderbek RJ, Treme GP, Miller MD. Bone-patella tendon-bone autograft anterior cruciate ligament reconstruction. *Clin Sports Med*. 2007;26(4):525-547.
33. Shaerf DA, Pastides PS, Sarraf KM, Willis-Owen CA. Anterior cruciate ligament reconstruction best practice: a review of graft choice. *World J Orthop*. 2014;5(1):23-29.
34. Shani RH, Umpierez E, Nasert M, Hiza EA, Xerogeanes J. Biomechanical comparison of quadriceps and patellar tendon grafts in anterior cruciate ligament reconstruction. *Arthroscopy*. 2016;32(1):71-75.
35. Slone HS, Romine SE, Premkumar A, Xerogeanes JW. Quadriceps tendon autograft for anterior cruciate ligament reconstruction: a comprehensive review of current literature and systematic review of clinical results. *Arthroscopy*. 2015;31(3):541-554.
36. Sonnier JH, Paul RW, Sando HE, et al. Patient decision making in anterior cruciate ligament reconstruction: a discrete choice experiment examining graft preference. *Orthop J Sports Med*. 2023;11(2):23259671221144983.
37. Spindler KP, Huston LJ, Zajichek A, et al. ACL reconstruction in high school and college-aged athletes: does autograft choice influence ACL revision rates? *Am J Sports Med*. 2020;48(2):298-309.
38. Tomita F, Yasuda K, Mikami S, Sakai T, Yamazaki S, Tohyama H. Comparisons of intraosseous graft healing between the doubled flexor tendon graft and the bone-patellar tendon-bone graft in anterior cruciate ligament reconstruction. *Arthroscopy*. 2001;17(5):461-476.
39. Wasserstein D, Sheth U, Cabrera A, Spindler KP. A systematic review of failed anterior cruciate ligament reconstruction with autograft compared with allograft in young patients. *Sports Health*. 2015;7(3):207-216.
40. West RV, Harner CD. Graft selection in anterior cruciate ligament reconstruction. *J Am Acad Orthop Surg*. 2005;13(3):197-207.
41. Zhao L, Lu M, Deng M, Xing J, He L, Wang C. Outcome of bone-patellar tendon-bone vs hamstring tendon autograft for anterior cruciate ligament reconstruction: a meta-analysis of randomized controlled trials with a 5-year minimum follow-up. *Medicine (Baltimore)*. 2020;99(48):e23476.

APPENDIX

TABLE A1
ACL Graft Preference Survey[a]

Questions	Answer Fields
1. Have you and your surgeon discussed your ACL graft preference?	(A) Yes, (B) no
2. Please write your age.	Patient writes in their age.
3. What is your sex?	(A) Male, (B) female, (C) other, (D) prefer not to answer
4. Please write the sport(s) in which you participate, if applicable.	Patient writes in their sport(s), if applicable.
5. Please write the sport or scenario in which you ruptured your ACL.	Patient specifies the scenario or sport in which they ruptured their ACL.
6. Do you have a primary sport?	(A) Yes, (B) no
7. Please write the number of months in which you participate in your primary sport, if applicable.	Patient writes in the number of months in which they participate in their primary sport, if applicable.
8. What is your highest level of education?	(A) Grade school, (B) some high school, (C) high school graduate/GED, (D) vocational/technical school, (E) some college, (F) college graduate, (G) postgraduate
9. Are you currently a student?	(A) Yes, high school; (B) yes, college; (C) yes, graduate school; (D) no
10. What is your current occupation?	(A) None, (B) heavy-lifting laborer, (C) light-lifting laborer, (D) sedentary job, (E) professional athlete, (F) disabled, (G) retired
11. Are you currently a collegiate athlete participating at the NCAA level?	(A) Yes, (B) no
12. Regarding your ACL reconstruction, please rank each of the following factors from 1 to 5 in order of most significant (1) to least significant (5) concern.	Patient ranks each of the following from 1 to 5: length of surgery, possibility of an ACL rerupture, other complications unrelated to a rerupture (knee stiffness, knee pain, infection), surgical incision length, ability to return to their desired level of athletics
13. Before your appointment today, have you independently researched or discussed graft options for ACL reconstruction with someone?	(A) Yes, (B) no
14. What was your source of information (select all that apply)?[b]	(A) Media, including the Internet or news source; (B) physician recommendation; (C) family member or friend; (D) athletic trainer or coach
15. Which graft was recommended based on your prior consultation with your physician?[c]	(A) BPTB autograft, (B) HT autograft, (C) QT autograft, (D) allograft
16. Based on the information provided, which graft would you prefer?	(A) BPTB autograft, (B) HT autograft, (C) QT autograft, (D) allograft
17. Which factor most influenced your graft preference selection in the previous question?	(A) Graft usage in professional athletes, (B) reported failure rates, (C) prior surgeon recommendation, (D) no influence, (E) postoperative knee pain, (F) other reason not listed, (G) other complications such as knee stiffness or infections, (H) family's or friend's input, (I) athletic trainer's or coach's input

[a]Before the questions were administered, the survey provided patients with information on the different ACL graft options as well as the motive behind ACL reconstruction. ACL, anterior cruciate ligament; BPTB, bone-patellar tendon-bone; GED, general educational development; HT, hamstring tendon; NCAA, National Collegiate Athletic Association; QT, quadriceps tendon.

[b]This question was only shown if the answer to question 13 was "yes."

[c]This question was only shown if the answer to question 1 was "yes."

TABLE A2
Evidence-Based Description of Graft Options[a]

Introduction to graft options:

1. BPTB autograft: The BPTB graft involves removing a small piece of bone from the lower kneecap (also known as the patella), the central third of the patellar tendon, and a small portion of bone from the shin.[7,10,19,23] The bone blocks at the end of the graft allow for reliable, strong, and rigid fixation of the graft in the bone tunnels, which is not possible with soft tissue (HT and QT) autografts.[7,10,16] This may also expedite the healing time of the graft. This is the most commonly used graft among professional and elite athletes, and studies suggest that it has the lowest rerupture rate and highest chance of allowing patients to return to their preinjury levels of activity.[5,7,10,16] The incision associated with this graft is larger than either the HT or QT graft, and it is associated with a higher incidence of pain in the front of the knee as well as with pain when kneeling.[16,19,23] There are also very rare postoperative complications such as kneecap fractures and patellar tendon ruptures.[7,10,16,19,23,29]
2. HT autograft: The HT graft is also commonly used as an ACL autograft. The graft is obtained through a smaller incision, and the procedure is associated with less pain immediately postoperatively compared to reconstruction with a BPTB graft.[4,5,7,16,18] Occasionally, the diameter of the HT graft is too small for reliable reconstruction, which has been shown to be a risk factor for postoperative failure . If this situation is encountered during surgery, an allograft is added to augment reconstruction; however, the addition of an allograft has not been proven to reduce the risk of postoperative failure. There are also concerns regarding removing the HT, as hamstring weakness is a known risk factor for ACL tears.[5,7,33] While some large database studies have found an increased risk of failure compared to BPTB grafts, other studies have demonstrated no increased risk of failure. Although the rates of infections after ACL reconstruction are low, HT autografts have been associated with the highest chance of infections.[4,5,7,16]
3. QT autograft: The QT autograft is the newest autograft and the least frequently used and studied. Despite this, its use is increasing. The graft can be obtained with a bone block from the kneecap on one end; however, most often, it is taken as a soft tissue graft.[5,7,27,35] The QT is significantly more robust (wider and thicker) compared to the patellar tendon, and patients have less pain in the front of the knee and while kneeling postoperatively compared to reconstruction with a BPTB graft. The harvest incision length is variable based on surgeon preference, but the graft can be obtained from a small, minimally invasive incision.[27,35]
4. Allograft: Allograft tissue comes from a deceased donor. The benefits include decreased morbidity associated with taking a graft from the patient and decreased surgical time. However, there are reports of early graft failure, particularly in younger patients.[5,8,9,18,20]

ACL outcomes data (within 3 years) from the largest available investigations:

Among several database studies comparing BPTB and HT grafts, the following has been found:

1. Among some registries (including in the United States), HT grafts were slightly more likely to result in revision surgery compared to BPTB autografts, while other registries have found no difference in revision rates between HT and BPTB grafts.[4-6,10,11,16] The QT graft was not investigated. The greatest difference in revision ACL reconstruction rates appeared to occur within 1 year of surgery, while this difference was not as pronounced after multiple years.[4-6,10,11,16,28]
2. Some studies comparing BPTB, HT, and QT autografts found similar reoperation rates between 2% and 4%. Pain in the front of the knee was higher in the BPTB group compared to both the HT and QT groups.[1,4,5,10,31-33]
3. Reconstruction with an allograft has been found to have an acceptable failure rate (~8%) in patients older than 40 years. The rate of failure is higher in younger patients.[5-7]

Bottom line:

1. The BPTB autograft is associated with increased pain in the front of the knee and kneeling pain after surgery.
2. Some studies have shown a decreased failure rate with BPTB grafts compared to HT autografts, while others have not.
3. No studies have identified a difference in failure rates between BPTB and QT grafts or between HT and QT grafts .
4. Allografts demonstrate acceptable failure rates in patients older than 40 years.

[a]ACL, anterior cruciate ligament; BPTB, bone-patellar tendon-bone; HT, hamstring tendon; QT, quadriceps tendon.