RESEARCH ARTICLE

Double and Single Bundle in Athletes: A Comparison in Medium and Long-Term Rates to Return to Sport and Re-Injury

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Abstract

Objectives: Compare, retrospectively, the medium- and long-term of return to sport rates and re-injury of the anterior cruciate ligament (ACL) in patients submitted to single-bundle (SB) compared to double-bundle (DB) technique reconstruction.

Methods: Athletes operated by SB or DB ACL reconstruction, with at least five years of follow-up at a single center, were included. The following data were collected: demographic data; competitive sports practice before the injury; previous surgery; injury/surgery to the contralateral knee; return to sports and level of the return; re-injury (time of the re-injury after the first surgery; mechanism of trauma for the re-injury; necessity of operative treatment); signs and complaints related to the knee the last clinical consultation.

Results: Seventy-six athletes (27 SB and 49 DB) were included. The return to sport rate (98%) was the same for both groups, and the return to the previous level rate showed an improvement in the DB group but without statistical significance (63% vs. 79%; P = 0.173). However, other outcomes showed higher results for the DB group: lower re-injury rate throughout the follow-up period (41% vs. 18%; P = 0.034) and during the first year of follow-up (22% vs. 4%; P = 0.021), and less stiffness (0% vs. 22%, P = 0.001). While in primary reconstruction cases, there was not a higher re-injury rate using SB (P = 0.744), in the revision cases, SB was correlated with more re-injuries than DB (P = 0.002).

Conclusion: The overall re-injury in the medium- and long-term and the return to practice sports at the same level as before surgery in athletes submitted to DB reconstruction were slightly better than those submitted to SB reconstruction, especially in the cases that were asecond time lesion (revisioned knees).

Level of evidence: II

Keywords: Anterior cruciate ligament, Arthroscopy, Athletes, Double-bundle, Knee, Sport

Introduction

The anterior cruciate ligament (ACL) is an important stabilizer of anterior and translational movements of the tibia to the femur. Several studies through the decades have demonstrated that the ligament consists of two bundles: the anteromedial (AM) and the posterolateral (PL). The AM mainly stabilizes translation in the anterior direction, while the PL stabilizes rotation.[1] Single-bundle (SB) reconstruction has the focus on reconstructing the isolated AM bundle or a SB fixed to the femur between the anatomical locations of the two bundles.

Double-bundle (DB) technique aim to achieve an anatomical reconstruction focusing in increasing rotational stability, based on what is evident in several biomechanical studies.[2,3]

It is possible to find several types of studies comparing the ACL techniques, often with controversial results. The majority of the studies developed were biomechanical, some in vivo and few controlled clinical studies, those all have already shown that the results with the DB shows better knee stability, but most of them had similar clinical

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results when compared with SB.[4,5] Two studies with interesting different results were Zaffagnini *et al*. (2011) and Jarvela *et al*. (2017), which both demonstrated lower rates of re-surgery and better functional outcomes in the DB group.[6,7] An review, in 2019, investigate 26 randomized prospective trials and showed that outcomes were improved in patients submitted to the DB technique in reference to stability and clinical outcomes.[8]

Although not all studies shows clinical improvement, the majority of them follows up the subjects for short or medium periods (less than five years), and fewer ones observes variables such as graft´s stability or rate of failure, associated conditions such as osteoarthritis, and return to sporting activities.[9-11] A meta-analysis with studies that took over five years of follow-up did not show differences between SB and DB ACL reconstruction when analyzing functional scores, clinical stability, and osteoarthritis.[12] However, when randomized comparative studies with more than five years of follow-up are analized, regarding re-injury rate, better results are shown in the DB group.[13,14] However, a more recent study did not demonstrate significant functional differences in at least five years of follow-up and in 2019, a randomized clinical trial did not showed any functional improvement and/or decrease in re-injuries rates in relation with on or other technique.[15,16]

We have operated our patients using the DB technique since 2006, but not exclusively. This is a research line of our group, and a larger cohort study is being performed comparing techniques retrospectively in athletes. D'Elia *et al*. organized a study that compared the rotation of the knee in our movement analysis laboratory. Although there was a tendency for better rotational control in patients submitted to DB reconstruction, the results were not statistically significant.[17,18] The objective of the present study is to offer a retrospective comparison between patients that went to ACL surgery using DB vs. SB with at least five years of follow-up, in concern to the return to sports and re-injury rates.

Materials and Methods

This retrospective comparative study was performed in a unique center. The study was approved by the Institutional Review Board (IRB). Medical records were reviewed, and patients submitted to ACL reconstruction between 2006 and 2015 with more than five years of follow-up were gathered. Inclusion criteria were subjects submitted to only ACL reconstruction without any other lesions, with SB or DB, with at least five years of follow-up, cases with or without previous ACL reconstruction, competitive sports athletes, and both sexes.

Exclusion criteria were reconstruction concurrent to other surgeries (osteotomy, meniscus repair, meniscectomy, cartilage transplants, and concomitant reconstruction of another ligament), loss to follow-up, or incomplete data on the medical record.

The technique chosen was kept the same as already reported in this section and was performed by four surgeons from the group. Double-bundle ACL reconstruction was done using autologous grafts from the semitendinosus and gracilis tendon (STG) and fixed in two tibial and two femoral tunnels. After obtaining the graft, arthroscopy-assisted ACL reconstruction was done using anterolateral (AL), AM, and accessory portals.

The first tunnel performed was the AM on femur; for this, the arthroscope was positioned in the AL portal, and the tunnel was drilled in its anatomical position from the AM portal, with the knee flexed at 120 degrees.

The second tunnel executed was the PL femoral; for this, the arthroscope was positioned in the AM portal, and the tunnel was drilled in its anatomical position from the accessory AM portal, with the at 120 degrees of flexed knee.The next tunnels were the tibial PL and AM.

The entry point of the PL tunnel was anteriorly to the fibers of the medial superficial collateral ligament, with the tibial guide adjusted to 55 degrees. The entry point of the AM tunnel was more lateral, leaving a bone bridge of at least 1 cm between the tunnels, with the tibial guide adjusted to 45 degrees. The graft for the PL bundle was passed through the tunnel first, followed by the AM. Both bundles were fixed with a biodegradable interference screw in the femur and tibia.

The AM bundle was fixed with the at 45 degrees of knee flexion and the PL with the at 15 degrees of flexed knee.

The SB ACL reconstruction was performed according to Pinczewski *et al.*[19], while the DB ACL reconstruction followed the techniques described by Jarvela *et al.*[9] and Zelle *et al.*[20]. We harvested ipsilateral semitendinous (ST) and gracilis (G) autograft from all patients. Both bundles were fixed with bioabsorbable interference screws in the femur and tibia. The postoperative plan did not differ for the SB and DB groups. It consisted of flexibility exercises, restoration of muscle strength, and training of functional activities: closed kinetic chain exercises (2nd week), open kinetic chain exercises (12th week), running (14th week), plyometrics (24th week), and return to activities (36th week).

The following data and outcomes were collected: sex, age, previous surgery, ACL contralateral injury, return to sport and level, re-injury, time of the re-injury event, and reported symptoms at the last follow-up (pain, instability, stiffness).

The analysis was performed with qualitative and quantitative data descriptions. The student's t-test or Mann-Whitney test was performed to compare continuous outcomes, as needed. The presence or absence of qualitative outcomes was compared by the chi-square or Fisher's exact test, as needed. After reconstruction, Kaplan-Meier curves were used with log-rank analysis to study the graft survival curves (using reinjury as the event to define survival). The significance level was 95%, and the tests were performed using the software program SPSS.

Results

Between 2006 and 2015, 374 ACL reconstruction surgeries were performed in our service, including primary and revision. Of this total, 232 were performed using the SB technique and 142 using the DB technique. The SB group included 58 athletes, but only 27 were evaluated. The DB group included 69 athletes, but only 49 were evaluated, totaling 76 patients in our study.

The demographic data and clinical presentation before surgery are shown in [Table 1]. The groups were pairable in all items except for mean age, with the SB group being younger.

Table 1. Baseline demographic and clinical characteristics

	Single-bundle (n=27)	Double-bundle (n=49)	*P*-value
Athletes	27 (100%)	49 (100%)	0.999
Female/ Male	11 (41%)	15 (31%)	0.374
Age at the time of surgery (years)	22 ± 6 (15-38)	28 ± 10 (15-53)	0.003
Follow-up (years)	9.4 ± 2.0 (7-14)	9.0 ± 1.7 (5-12)	0.490
Previous meniscectomy	3 (11%)	5 (10%)	0.593
Primary reconstruction of the index ACL	21 (78%)	36 (73%)	0.532
ACL contralateral injury	9 (33%)	19 (39%)	0.639

Data is shown as mean ± standard deviation (minimum - maximum) or in absolute values (percentage of total cases). P-values shown in bold represent differences statistically significant

The surgical outcomes comparison is shown in [Table 2]. The equality of results for return to sport is evident in the groups. However, a higher ACL re-injury rate was found in the SB group, both in the total follow-up time (P = 0.034) and in the first 12 months after surgery alone (P = 0.021). Unlike the SB group (P = 0.001), all athletes in the DB group reported being free of knee stiffness at the last follow-up.

Table 2. Surgical outcomes

	Single-bundle (n=27)	Double-bundle (n=49)	*P*-value
Return to sport	26 (98%)	48 (98%)	0.587
Return to sport at the previous level	17 (63%)	38 (79%)	0.173
ACL re-rupture	11 (41%)	9 (18%)	0.034
up to 12 months postop	6 (22%)	2 (4%)	0.021
Re-rupture timing (months postop)	26 ± 25 (6-84)	34 ± 15 (9-50)	0.170
Case reporting pain (at last FU)	12 (44%)	15 (31%)	0.317
Case reporting instability (at last FU)	7 (26%)	6 (16%)	0.202
Case reporting stiffness (at last FU)	6 (22%)	0 (0%)	0.001

Data is shown as mean ± standard deviation (minimum - maximum) or in absolute values (percentage of total cases). FU = follow-up. P-values shown in bold represent differences statistically significant

A comparative analysis of re-injury rates in patients submitted to primary or revision surgeries can be seen in [Tables 3 and 4]. In primary reconstructions, there was no difference in the re-injury rates between the SB and DB groups (P = 0.744), while all the revision cases treated with SB evolved with re-injury, and only 15% in the DB group (P = 0.002).

Table 3. Re-rupture rate in primary reconstructions

	Single-bundle	Double-bundle	Total
Total	21 (100%)	36 (100%)	57
Re-rupture	5 (24%)	7 (19%)	12
No re-rupture	16 (76%)	29 (81%)	45

P-value = 0.744

Table 4. Re-rupture rate in revision reconstructions

	Single-bundle	Double-bundle	Total
Total	5 (100%)	13 (100%)	18
Re-rupture	5 (100%)	2 (15%)	7
No re-rupture	0 (0%)	11 (85%)	11

P-value = 0.002

The survival curves show lower evolution in the SB group [Figure 1A; *P* = 0.038], with evolution of re-injury for primary reconstructions with similar results between those treated with SB and DB, independently [Figure 1B; *P* = 0.680], and lower prognosis for revision with SB [Figure 1C; *P* < 0.001].

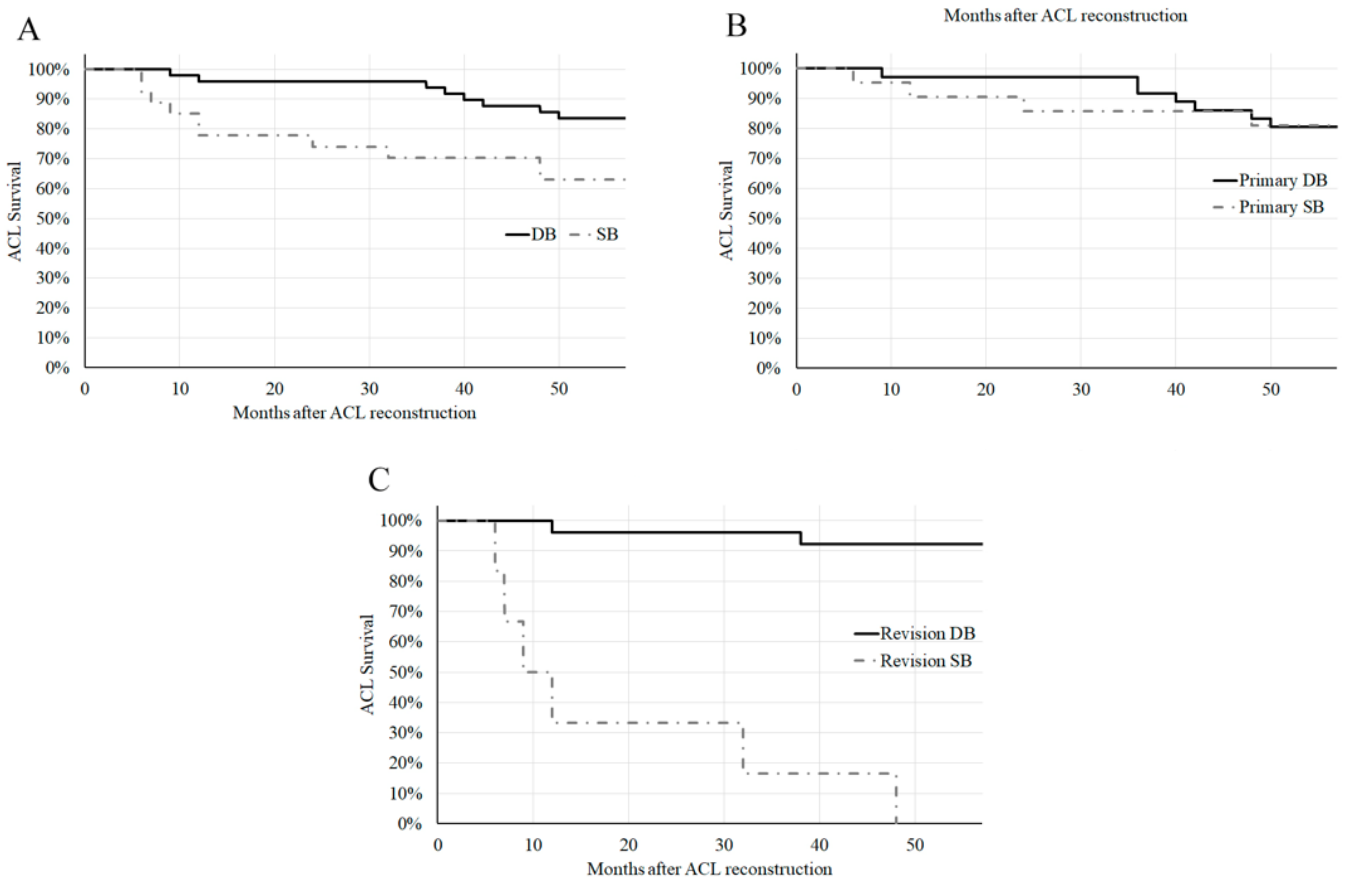

Figure 1. ACL graft survival (re-injury) curves after single-bundle (SB) or double-bundle (DB) reconstruction. (A) DB vs. SB; P = 0.038. (B) DB vs. SB in primary cases; P = 0.680. (C) DB vs. SB in revision cases; P < 0.001.

Discussion

Since 2006, we have done the DB technique in our institution, mostly in non competitive or even in competitive athletes with high demands or in revision situations, but without putting the SB technique aside. Since then, we have performed the SB technique through the AM portal, looking for a more anatomical reconstruction. The procedures of this study were performed with the same technique by four more senior surgeons in our group.

In 2010, a initial trial describing the methodology for evaluating knee rotation, demonstrated initial results comparing the knee reconstructed with DB and the contralateral knee.[17] In 2014, D'Elia *et al*. conducted a similar study, finding no significant biomechanical differences in knee rotation in subjects that went to ACL reconstruction with DB compared to SB reconstruction.[18] However, this study did not compare clinical results, recurrence of lesion rates and/or return to sports in a medium/long-term. It only investigated the short-term biomechanical results considered clinically successful in evaluating tibial rotation. Few studies in the literature compare the results of the DB and SB techniques with short follow-up times.[21] In our study, the most significant results for re-injury were a 25% general re-injury rate, with 37% re-injury in the SB group after a mean of 9.4 years after surgery. In the DB group, the re-injury rate was 18.34% after a mean of nine years of follow-up.

The re-injury rates in the literature ranges from 6% to 31%.[22] Higher rates are found in athletes compared to the

general population, according to the study conducted Wiggins *et al*. in 2016, this rate increases to 25% for athletes under the age of 25.[23]

When we compare our 25% general rate with studies with at least five years of follow-up, we believe that our results are comparable and positive for cases of DB (18.34%) because this is a sample with only athletes and with revision cases, in which re-injury rate increases, as demonstrated by George *et al.* (24% revision surgeries vs. 7% primary surgeries).[24] However, we consider this an unacceptable rate for SB cases (37%). When we stratified only primary cases, we did not find any differences between groups, and the rates were acceptable for the athlete population (24% SB vs. 19% DB). However, when we analyzed only revision cases, 100% of the patients in the SB group presented re-injury, while only 15% were in the DB group. Suomalainen *et al*. 2012, demonstrated a 25% re-injury rate in patients submitted to SB reconstruction, compared to 10% in DB reconstruction.[25] Finally, Grassi *et al*., in a more recent review with a minimum five years of follow-up, reported a cumulative failure rate (graft + objective scores and instability) of more than 5% in all but one of the 16 series studied[26]; more than 10% in 12 of 16 of the series studied, and more than 20% in five series.

Ultimately, a comparative study by Yoon *et al*., with the longest follow-up time in the literature, demonstrated 15-year survival rates following ACL reconstruction, 82.1% for SB and 83.7% for DB.[27] We believe that these high and variable rates demonstrate that this is a multifactorial cause involving technical surgical and biological issues, including graft integration and volume and postoperative neuromuscular control.In our study, two cases of failure from each group did not follow the discharge criteria, corroborating the data presented by Kyritsis *et al*. and other groups that demonstrate the importance of neuromuscular control in preventing re-injury.[28]

Regarding return to sport, we believe that we had a good rate, 98% in both groups, with a slightly superior rate in the DB group to the previous level post-reconstruction (79% vs. 63% in the SB group), although this difference had no statistical significance ($P = 0.173$).

Sepúlveda *et al*., in a review conducted in 2017, reported that 81% of patients returned to sports, 65% to the same level as pre-injury.[29] Lai *et al*. in 2018 report that this rate of return to pre-injury levels is higher among elite athletes (83%).[30] Finally, Volpi *et al*., in a case series of DB patients with 4–11 years of follow-up, report that 100% returned to sports, 90.5% to the same level as pre-injury.[31]

Finally, athletes submitted to DB reconstruction reported less knee stiffness than the SB group ($P = 0.001$). Since we did not evaluate patients objectively and did not perform prior imaging exams, it may be that the more functional reconstruction in this group of athletes leads to an improvement in stiffness in the medium to long-term periods. This may be because this method maintains the joint space and evolves with less osteophytosis.

Our study has some limitations, mainly linked to its design. In addition to these issues, the low number of subjects may underestimate differences between the subgroups compared. Our sample also had age differences, with older patients in the DB group than those in the SB. It was not possible to evaluate either clinical or functional scores, and we did not evaluate the arthrosis progress, an important long-term variable. Finally, we had a large sample loss (29% in the DB group and 53.4% in the SB group), considering all patients operated in the studied period. The number of losses to follow-up tolerated in case series is much debated, with authors citing around 50% as adequate, but losses of below 20% are the ultimate goal.[32] It should also be considered that losses to follow-up will be greater in series with longer follow-up times. A future perspective on this topic would be an analysis that considers the graft diameter/ footprint used (independently or in combination with the information if it is SB or DB). Unfortunately, in our retrospective study, we did not have such information for every patient.

However, we believe that our study is relevant because it has been performed at one center that evaluated only athletes using the same techniques, with a long follow-up time, and with two outcomes that have been little investigated in the literature: the return to sport and long-term re-injury rates.

Conclusion

In our series of athletes operated on with the double-bundle technique, we obtained better results in re-injury rate, both in cases of primary surgery – though without statistical significance to the simple-bundle group – and much better rates in cases of revision surgeries with the double-bundle technique. We therefore question the single-bundle technique for athletes requiring revision surgery. Regarding the return to sport rate, both techniques obtained good results, with a 98% return to sport and a tendency towards better results compared to pre-injury levels for the group submitted to the double-bundle technique.

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References

1. Ahldén M, Sernert N, Karlsson J, Kartus J. A prospective randomized study comparing double- and single-bundle techniques for anterior cruciate ligament reconstruction. Am J Sports Med. 2013; 41 :(11):2484–2491. doi: 10.1177/0363546513497926.
2. Komzák M, Hart R, Feranec M, Šmíd P, Kocová R. In vivo knee rotational stability 2 years after double-bundle and anatomic single-bundle ACL reconstruction. Eur J Trauma Emerg Surg. 2018; 44:105–111. doi: 10.1007/s00068-017-0769-7.
3. Kondo E, Merican AM, Yasuda K, Amis AA. Biomechanical comparisons of knee stability after anterior cruciate ligament reconstruction between 2 clinically available transtibial procedures: Anatomic double bundle versus single bundle. Am J Sports Med. 2010; 38(7):1349–1358. doi: 10.1177/0363546510361234.
4. Björnsson H, Desai N, Musahl V, et al. Is double-bundle anterior cruciate ligament reconstruction superior to single-bundle? A comprehensive systematic review. Knee Surg Sports Traumatol Arthrosc. 2015; 23(3):696–739. doi:0.1007/s00167-013-2666-x.
5. Qiu XS, Jiang H, Qian BP, et al. Influence of prone positioning on potential risk of aorta injury from pedicle screw misplacement in adolescent idiopathic scoliosis patients. J Spinal Disord Tech. 2014; 27(5):E162–E167. doi: 10.1097/BSD.0000000000000075.
6. Zaffagnini S, Bruni D, Marcheggiani Muccioli GM, et al. Single-bundle patellar tendon versus non-anatomical double-bundle hamstrings ACL reconstruction: a prospective randomized study at 8-year minimum follow-up. Knee Surg Sports Traumatol Arthrosc. 2011; 19:390–397. doi: 10.1007/s00167-010-1225-y.
7. Järvelä T. Double-bundle versus single-bundle anterior cruciate ligament reconstruction: a prospective, randomize clinical study. Knee Surg Sports Traumatol Arthrosc. 2007; 15(5):500–507. doi: 10.1007/s00167-006-0254-z.
8. Kong L, Liu Z, Meng F, Shen Y. Single-bundle versus double-bundle anterior cruciate ligament reconstruction: A systematic review and meta-analysis. Int J Clin Exp Med. 2017; 10(1):1–15.
9. Järvelä T, Moisala AS, Sihvonen R, Järvelä S, Kannus P, Järvinen M. Double-bundle anterior cruciate ligament reconstruction using hamstring autografts and bioabsorbable interference screw fixation: prospective, randomized, clinical study with 2-year results. Am J Sports Med. 2008; 36(2):290–297. doi: 10.1177/0363546507308360.
10. Yoon KH, Kim EJ, Kwon YB, Kim SG. Minimum 10-Year Results of Single- Versus Double-Bundle Posterior Cruciate Ligament Reconstruction: Clinical, Radiologic, and Survivorship Outcomes. Am J Sports Med. 2019; 47(4):822–827. doi: 10.1177/0363546518825257.
11. Bitar AC, Scalize AR, Abreu G, D'Elia C, Ribas LH, Castropil W. Return to Sport and Re-Injury Rate after Double-Bundle Anterior Cruciate Ligament Reconstruction with at least Five Years of Follow-Up. Arch Bone Joint Surg. 2021; 9(6):653–658. doi: 10.22038/ABJS.2021.52664.2605.
12. Dong Z, Niu Y, Qi J, Song Y, Wang F. Long term results after double and single bundle ACL reconstruction: Is there any difference? A Meta - analysis of randomized controlled trials. Acta Orthop Traumatol Turc. 2019; 53(2):92–99. doi: 10.1016/j.aott.2018.12.004.
13. S Svantesson E, Sundemo D, Hamrin Senorski E, et al. Double-bundle anterior cruciate ligament reconstruction is superior to single-bundle reconstruction in terms of revision frequency: a study of 22,460 patients from the Swedish National Knee Ligament Register. Knee Surg Sports Traumatol Arthrosc. 2017; 25(12):3884–3891. doi: 10.1007/s00167-016-4387-4.
14. Jarvela S, Kiekara T, Suomalainen P, Jarvela T. Double-Bundle versus Single-Bundle Anterior Cruciate Ligament Reconstruction: A Prospective Randomized Study with 10-Year Results. Am J Sports Med. 2017; 45(11):2578–2585. doi: 10.1177/0363546517712231.
15. Mohtadi NG, Chan DS. A Randomized Clinical Trial Comparing Patellar Tendon, Hamstring Tendon, and Double-Bundle ACL Reconstructions: Patient-Reported and Clinical Outcomes at 5-Year Follow-up. J Bone Joint Surg. 2019; 101(11):949–960. doi: 10.2106/JBJS.18.01322.
16. Mayr HO, Bruder S, Hube R, Bernstein A, Suedkamp NP, Stoehr A. Single-Bundle versus Double-Bundle Anterior Cruciate Ligament Reconstruction—5-Year Results. Arthroscopy. 2018; 34(9):2647–2653. doi: 10.1016/j.arthro.2018.03.034.
17. D'Elia CO, Bitar AC, Castropil W, et al. Anterior cruciate ligament reconstruction using the double bundle technique - evaluation in the biomechanics laboratory. Rev Bras Ortop. 2015; 46(2):148–154. doi: 10.1016/S2255-4971(15)30231-7.
18. D'Elia CO. Estudo comparativo da avaliação da rotação dos joelhos submetidos à reconstrução do ligamento cruzado anterior: feixe duplo x feixe simples. São Paulo: Faculdade de Medicina da Universidade de São Paulo; 2014.
19. Pinczewski LA, Deehan DJ, Salmon LJ, Russell VJ, Clingeleffer A. A five-year comparison of patellar tendon versus four-strand hamstring tendon autograft for arthroscopic reconstruction of the anterior cruciate ligament. Am J Sports Med. 2002; 30(4):523–536. doi: 10.1177/03635465020300041201.
20. Zelle BA, Brucker PU, Feng MT, Fu FH. Anatomical double-bundle anterior cruciate ligament reconstruction. Sports Med. 2006; 36(2):99–108. doi: 10.2165/00007256-200636020-00001.
21. Gobbi A, Karnatzikos G, Lad DG. Single Versus Double ACL Reconstruction in Athletes. In: Sports Injuries. Doral M. KJ, eds.Springer, Berlin, Heidelberg; 2014.
22. Wright RW, Magnussen RA, Dunn WR, Spindler KP. Ipsilateral graft and contralateral ACL rupture at five years or more following ACL reconstruction: A systematic review. J Bone Joint Surg Am. 2011; 93(12):1159–1165. doi: 10.2106/JBJS.J.00898.
23. Wiggins AJ, Grandhi RK, Schneider DK, Stanfield D, Webster KE, Myer GD. Risk of Secondary Injury in Younger Athletes after Anterior Cruciate Ligament Reconstruction. Am J Sports Med. 2016; 44(7):1861–1876. doi: 10.1177/0363546515621554.

24. George MS, Dunn WR, Spindler KP. Current concepts review: Revision anterior cruciate ligament reconstruction. Am J Sports Med. 2006; 34(12):2026–2037. doi: 10.1177/0363546506295026.
25. Suomalainen P, Järvelä T, Paakkala A, Kannus P, Järvinen M. Double-bundle versus single-bundle anterior cruciate ligament reconstruction: A prospective randomized study with 5-year results. Am J Sports Med. 2012; 40(7):1511–1518. doi: 10.1177/0363546512448177.
26. Grassi A, Kim C, Marcheggiani Muccioli GM, Zaffagnini S, Amendola A.What Is the Mid-term Failure Rate of Revision ACL Reconstruction? A Systematic Review. Clin Orthop Relat Res. 2017; 475(10):2484–2499. doi: 10.1007/s11999-017-5379-5.
27. Yoon KH, Kim JS, Kim SJ, Park M, Park SY, Park SE. Eight-year results of transtibial nonanatomic single-bundle versus double-bundle anterior cruciate ligament reconstruction: Clinical, radiologic outcomes and survivorship. J Orthop Surg (Hong Kong). 2019; 27 :(2):2309499019840827. doi: 10.1177/2309499019840827.
28. Kyritsis P, Bahr R, Landreau P, Miladi R, Witvrouw E. Likelihood of ACL graft rupture: Not meeting six clinical discharge criteria before return to sport is associated with a four times greater risk of rupture. Br J Sports Med. 2016; 50(15):946–951. doi: 10.1136/bjsports-2015-095908.
29. Sepúlveda F, Sánchez L, Amy E, Micheo W. Anterior cruciate ligament injury: Return to play, function and long-term considerations. Curr Sports Med Rep. 2017; 16(3):172–178. doi: 10.1249/JSR.0000000000000356.
30. Lai CC, Ardern CL, Feller JA, Webster KE. Eighty-three per cent of elite athletes return to preinjury sport after anterior cruciate ligament reconstruction: A systematic review with meta-analysis of return to sport rates, graft rupture rates and performance outcomes. Br J Sports Med. 2018; 52(2):128–138. doi: 10.1136/bjsports-2016-096836.
31. Volpi P, Quaglia A, Carimati G, Galli M, Papalia R, Petrillo S. Double bundle anterior cruciate ligament reconstruction: Failure rate and patients-reported outcomes at 4-11 years of follow up. J Orthop. 2019; 16(3):224–229. doi: 10.1016/j.jor.2019.02.021.
32. Babbie ER, eds. Survey research methods.2nd ed. Cengage Learning, Boston; 1973.