Why do anterior cruciate ligament reconstruction Fail; Failure rate and Causes.

Malek Mustafa Ghnaimat MD, Almuthana Musleh Alymani MD, Mohannad Ahmad Alodat MD, Mohammad Ahmad Abushahot MD, Mohammad Ali Alsukour MD.

ABSTRACT

Objectives: The purpose of this study was to determine the failure rate and to analyse failure aetiology among patients who undergone primary ACL (anterior cruciate ligament) reconstruction with a description of our experience; as we have obtained good results in most of our patients.

Methods: In our Sport Surgical Department between April 2012 and November 2018, we operated on 934 patients with single bundle ACL reconstruction. Surgeries were performed by one team composed of two experienced sport surgeons and two trained- fellows in sport surgery. A total of 54 patients (23 left knees and 31 right knees) were planned for ACL revision after evaluating them clinically and radiologically. Although there is debate about the definition of ACL, we defined failure as requiring revision if there was objective clinical failure that met one or more of the following: Lachman grade II or III, pivot shift grade II or III, KT-1000/2000 > 5 mm, and/or overall IKDC score C or D. Exclusion criteria included history of prior ACL reconstruction failure, presence of concomitant ligament injuries, and complex regional pain syndrome. Instability examination, CT and MRI were done for all patients that met our criteria for failure, and the data collected for all cases before revision surgery included graft type, tunnel drilling technique, graft fixation systems used, Lysholm score, subjective and objective IKDC scores and questionnaire (including whether a traumatic event was absent or present causing instability).

Result: The failure rate of primary ACL reconstruction was 5.8%. Non-traumatic cause was responsible for the failure in 59.3% of cases, 25.9% due to technical error with aberrant femur tunnel was found as the most common (72.7%).There was significant correlation between non-anatomical femur tunnel and non-traumatic failed cases *(P<0.05)*. 40.9% of traumatic failed cases were also found to have technical error. Non-traumatic cause is responsible for early ACL revision with significant P-value (*p<0.05*) and there was no significant graft failure difference between adjustable loop and interference screw graft fixation system (*P>0.05)*. An elongated graft was the most common mode of graft failure pattern identified arthroscopically in 59.6% of cases.

Conclusion: The best chance to achieve successful ACL reconstruction surgery is in primary index surgery with success rate more than 85%. However, awareness about aetiologies of failure that could considerably overlap is crucial. Non-traumatic causes might be the primary cause for the revision. Despite improvements in surgical techniques, fixation devices, and ACL anatomy, more effort may be needed to lessen the incidence of failure among studies.

Keywords: anterior cruciate ligament, reconstruction, ACL failure, ACL revision

RMS December 2021; 28(3): 10.12816/0059542

Introduction

There is agreement that anterior cruciate ligament reconstruction surgery is the best surgical modality to restore

* From the departments of:
Orthopedics, JRMS, KHMC, Amman, JORDAN.
Correspondence should be addressed to Mohammad Ali Alsukour MD; E-mail: dr.mohammed_sagoor@yahoo.com

the kneeCs articular stability, improve symptoms and return to preinjury level (1-5). There is also a considerable increase in both the incidence and number of cases performed annually, with a subsequent increase in the revision surgeries being performed (5). Reported rates of ACL failure after reconstruction surgery vary among the literature, with revision rates running between 4% (6) and 13% (7).Many studies have been conducted to identify the potential factors that influence the revision of ACL reconstruction (8-13). Patient factors have been identified as risk factors for ACL reconstruction failure, including age, gender, body mass index (BMI) and hyperlaxity (10). Bony morphology has also been reported to be an important risk factor (11,12,13)
The causes of ACL reconstruction failure are typically classified under three categoriesncluding age, gender, body mass index (BMI) and hyperlaxityeries being performedded t stated that the mode of ACL reconstruction failure was traumatic in 32% of cases, technical in 24% of cases, biological in 7% of cases, and combined in 37% of cases (8,9). Additionally, there was a debate among the studies about which mode of failure was the most commonly identified. Some studies have reported that traumatic rupture was the most common cause, while other studies have cited technical error (specifically tunnel position) as the most common cause (5).
It is important to mention that there is no undisputed definition for the term e was the most commonly identified. Some studies have reported that traumatic rupture was the most common cause, while other studies have cited technical error (specifically tune attempting to specify the mode of failure (14).
We have categorized the majority of patients under the above mentioned system (traumatic, technical and biological), but we believe that the application, elaboration and maybe amplification of this system might assist us in understanding more the factors that could influence failure in our ACL reconstruction surgeries with incorporation of all aetiologies which could help to identified which cause of failure might be the dominant one depending on the findings that were observed in failed surgeries.

MATERIAL AND METHODS

- Institutional review board approval was obtained.
- Consent forms were obtained for 54 patients.

In Prince Hashem Ibn Al-Hussein and Queen Alia Military Hospitals at Sport Surgical Department, we operated on 934 patients with single bundle ACL reconstruction between April 2012 and November 2018. Surgeries were performed by one team composed of two experienced sport surgeons and two fellows in sport surgery. A total of 54 patients (23 left knees and 31 right knees) were retrospectively reviewed and planned for ACL revision after evaluating them clinically and radiologically. The average age of patients was 31.5 years (range 22–48 years), average BMI was 24.1 kg/m^2 (range 18–36 kg/m^2), and all were males.
(Table I) All the patients were exposed to the same rehabilitation protocol. In 53 cases, quadruple (4-strand) hamstring autograft (gracilis and semi-T) with size range 7 9 mm was used and an allograft cryopreserved peroneus longus tendon size 8 mm was used in one case. All cases were done via the (transportal) anteromedial portal anatomical ACL reconstruction technique with femur tunnel. In 37 cases, we used the ToggleLoc Device with medial portal adjustable Zip Loop Technology, while in 17 cases, we used PEEK biodegradable interference screw system to fix the graft to the femur tunnel with a tunnel length 15ue with femur tunnel. In 37 cases, we used the ToggleLoc Device with medial portal adjustable reviewed and planned fo point fixation was used to decrease the risk of graft slippage after fixation. All the patients were evaluated radiologically and clinically preoperatively and examination was performed under general anaesthesia and stability was checked just after reconstruction.

Table I: Demographic data of the 54 subjects

	Ratio	Mean	SD	Range
Gender (M:F)	54:0			
Time of injury to index surgery		7.8 m	7	(3 weeks–45 months)
Age at index ACL reconstruction (y)		31.5	5.9	(22–48)
Average time between index surgery and revision (m)		27 m		(6–60)
Graft type Autograft:Allograft	**53:1**			

While there is controversy about the definition of ACL failure, we defined failure as requiring revision if there was objective clinical failure that met one or more of the following: Lachman grade II or III, pivot shift grade II or III, KT-1000/2000 > 5 mm, and/or overall IKDC score C or D (15). Exclusion criteria included history of prior ACL reconstruction failure, presence of concomitant ligament injuries, complex regional pain syndrome, contralateral side injury and insufficient data about the technique used or mode of failure. Instability examination, CT and MRI were done for all patients that met our criteria for failure, and the data collected for all cases before revision surgery included graft type, tunnel drilling technique, graft fixation systems used, integrity of articular cartilage and status of meniscus, Lysholm score, subjective and objective IKDC scores (16) (17) and questionnaire (including whether a traumatic event was absent or present causing instability). In addition to radiological and clinical assessment, arthroscopic identification of articular cartilage status, menisci, tunnel positions, mode of graft rupture and possible reason for failure of fixation in revised cases.

Both femur and tibia tunnel positions were evaluated by CT scan using radiographic measurement methods according to the Bernhard and Hertel grid, considering it anatomically if the centre of the femur tunnel was within a range depth of 19 of 19cording to the Bernhard and xation syndrome, contralateral sideithin a range of 30–44% in the CT scan measurements (18) (19) . The measurement values were determined by two experienced radiologists.

At index surgery, both menisci were normal in 27 cases. The medial meniscus was affected in 56% of cases, while the lateral meniscus was affected in 44% of cases. In 20 cases, partial resection was done, while repair was done in five cases. In two cases, lateral stable meniscus tears were left untreated.

The mode of failure was determined by two experienced sport surgeons in the team and classified according to the system described by Wright et al. (9), which considered the failure as traumatic if there was a history of a traumatic event causing recurrent laxity, despite other factors; technical when a technical cause was identified with no evidence of trauma; and biological when there was no trauma or technical cause that could be identified. The normality of the quantitative variables was verified using the Shapiro-Wilk test. Qualitative variables were compared using the Chi2 test or the Fishersherc event causinneeded. The distribution of quantitative variables was compared using the unpaired Studentent causing recurrent laxity, despite other facn the variables were not normally distributed. A significance threshold of 0.05 was chosen for all the statistical testing. IBM SPSS software version 22.0 was used.

RESULTS

The results of the subjective evaluation of the satisfaction of patients and objective evaluation after the primary ACL reconstruction using the IKDC score were low. The average score of the IKDC subjective evaluation was 51.8 (range 15–96) preoperatively and 62 postoperatively. However, preoperative IKDC objective evaluation after recovery was as follow: 96% of patients graded as C or D (C was 49% and D was 43%) and 4% of patients graded as B. The mean Lysholm score, which was translated in our institution, was 47.3 (26s graded as B.uation after the primary ACL reconstruction using fair score (65–83), while 47 patients had a poor score (< 65) (20) ***chart-1.***

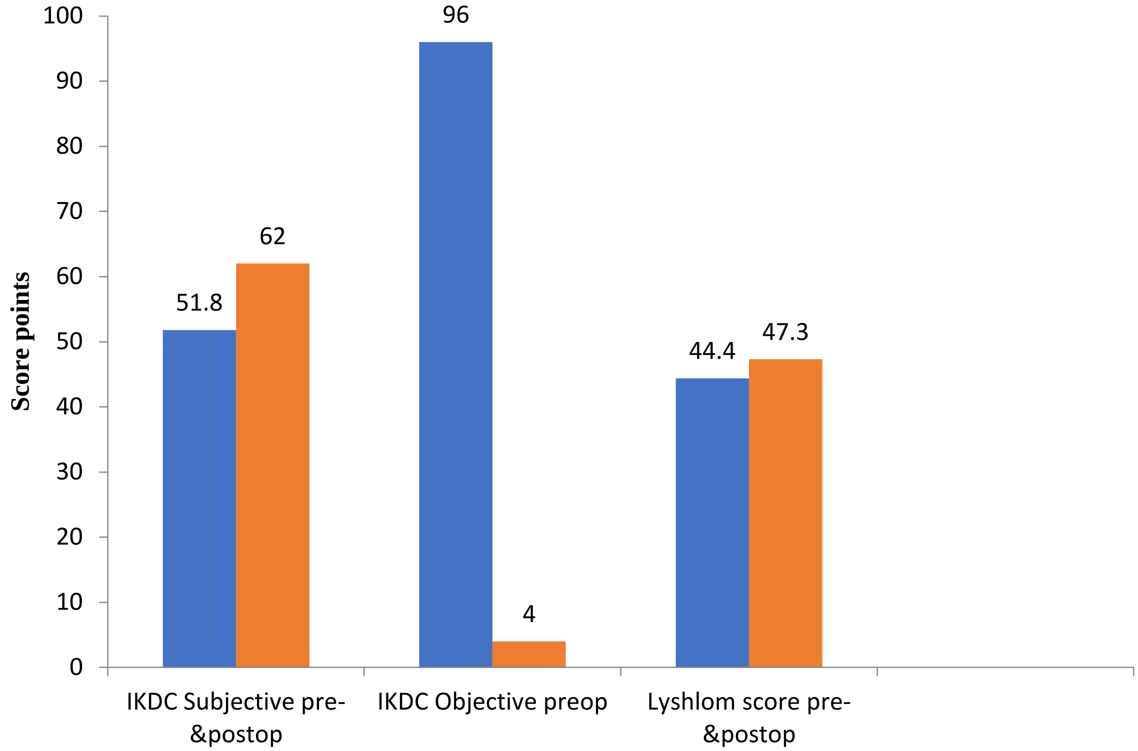


chart-1. International Knee Documentation Committee and Lyshsholm score results

The average time of injury to index surgery was 7.8 months (range 3 weeksjury to index surgery was 7ur institution, was 47.3 (26s graded as B.uati was 15.7 months (range 6 months–61 months).

Based on the aforementioned classification, we have two groups of patientss 7ur institution, wastraumatic event manifested by pain, swelling and difficulty bearing weight either contact or non-contact consisted of 22 patients (40.7%) and those showing gradual onset of recurrent laxity consisted of 32 patients (59.3%). Of those non-traumatic cases, 14 cases (25.9%) were found to have technical errors, 11 cases (20.3%) were due to biological factors, 3 cases (5%) missed other ligaments (missed PLC/FCL), 3 cases (5%) had mechanical malalignment with either varus thrust or a posterior tibial slope of 12 degrees or more, and 1 case (1.8%) had an infected ACL ***(Table II) (Figure-1&2).***

Table II: Aetiology of failure following primary single bundle ACL reconstruction

Causes	Frequency	Ratio in all subjects	Combined other causes
Traumatic	22	40.7%	9 technical
Non-traumatic	32	59.3%	
Technical	14	25.9%	
Misalignment	3	5%	
Missed other ligaments	3	5%	
Infection	1	1.8%	
Total	**54**		

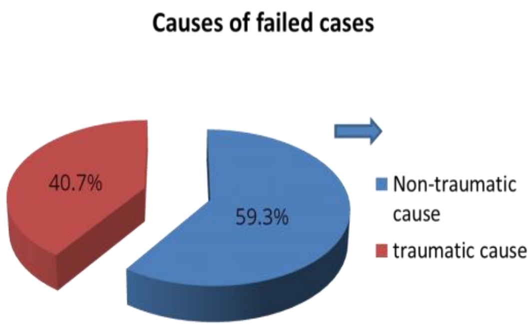


Fig 1. Ratio of Traumatic and Non-traumatic group.

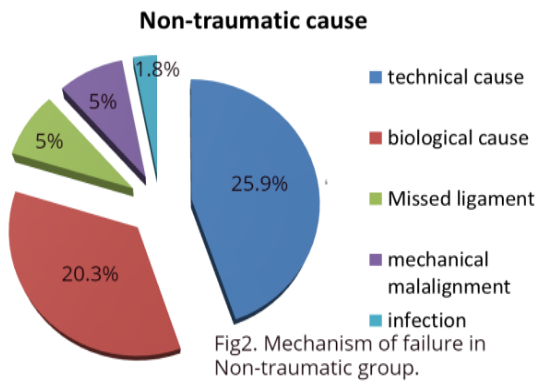
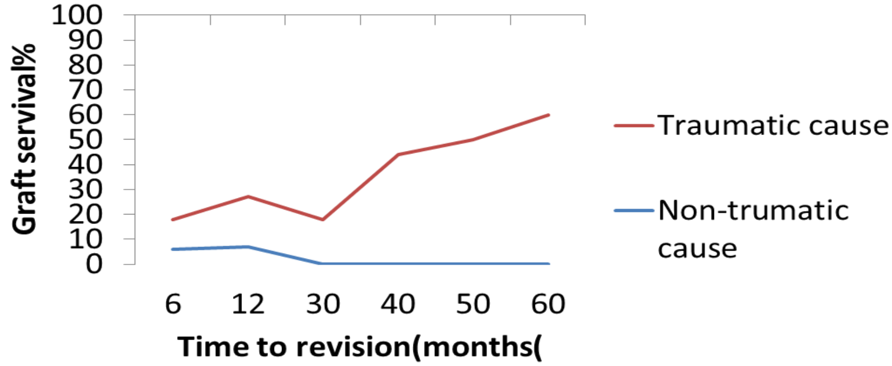


Fig2. Mechanism of failure in Non-traumatic group.

In traumatic cases, 5 cases occurred within the first 6 months of index surgery, 6 cases between 7 and 12 months of index surgery and 11 cases after 1 year of index surgery (mean 22.0 ed within th
However, the average time of revision from index surgery was 23.4 months SD 18 for traumatic cases, while it was 10.6 months SD 3.1 for non-traumatic cases, indicating that failure due to non-traumatic causes led to revision surgery earlier than failure due traumatic causes, with a significant difference P=0.029($p < 0.05$) ***(Figure-3).***

Fig3. **Comparison of time between primary and revision surgery in the traumatic and non-traumatic group**



Regarding technical causes, tunnel malposition was identified as the most common cause of failure, 11 cases out of 14 (78.6%). A non-anatomical anterior femur tunnel was found in eight cases (72.7%), a non-anatomical tibial tunnel was found in three cases (27.3%), breach of the posterior cortex of the femur tunnel was found in one case, and screw divergence > 15 degrees in the tibia tunnel was found in two cases. However, in traumatic failure patients, nine cases were found to also have an aberrant tunnel position (40.9%). A non-anatomical femur tunnel was observed in six cases (66.7%), while a non-anatomical tibial tunnel was observed in three cases (33.3%). There was a significant correlation of femur tunnel malposition in non-traumatic failed cases P=0.0384($p < 0.05$) but not in the case of tibial tunnel malposition P=0.062($p > 0.05$) ***(Figure-4).***

Figure-4 first stage ACL revision for non-anatomical femur tunnel. (RMS-Sport Dep.)

At revision surgery, we could find an elongated graft failure pattern, which was verified arthroscopically in 59.6% of cases. In two cases, the pattern could not be identified. In 53.1% of the cases where the graft was fixed by an adjustable loop system, and it was statistically insignificant as compared to the subarticular interference screw P=0.059($p > 0.05$). However, 14 out of 17 of cases in the traumatic group that presented 7 months or more after index surgery had a proximal graft rupture pattern, which resembled a native ACL tear pattern ***(Figure- 5).***

Moreover, the remaining 4 cases of the traumatic group, as well 27 cases in the non-traumatic group, showed a lax graft arthroscopically.

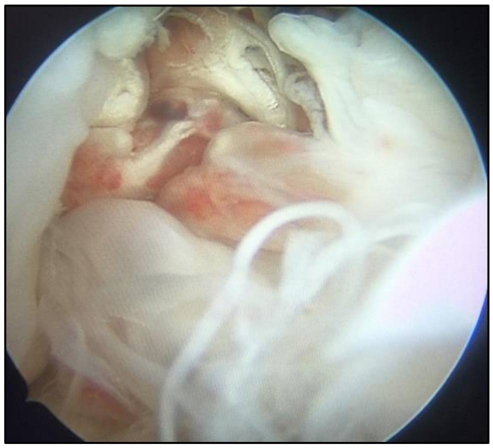


Figure-5. proximal ACL graft rupture due to trauma after 1 year of index surgery which is resemble native ACL rupture pattern(RMS-Sport Dep.).

DISCUSSION

Because of the patient satisfaction rates of revision ACL surgery are lower than those of primary ACL reconstruction, it is important to identify the possible underlying aetiology behind the failed cases. In this study, we have been trying to represent our experience in a systematic approach to these cases. In general, the causes of primary ACL reconstruction can be designated into three categories: traumatic event, technical error and biological factor. However, we could add missing other ligaments and mechanical misalignment as potential factors when the failed cases could not be categorized under the aforementioned classification and a biological factor was excluded.

Non-traumatic causes as technical errors in patients who experienced gradual onset of recurrent instability were found to be the most common finding in 22–79% of failed cases (5), while a large prospective study conducted by the MARS group cited traumatic failure in 32% and technical failure in 24% of cases (8) (9). Therefore, there is no indication in studies regarding the most prevalent cause responsible for ACL failure. Such an issue could be explained by variability in assessment of the mode of failure among the surgeons and relies solely on who did the revision for the failed cases with enforcement of a lack of clear definition for failure. Additionally, there could be many factors playing a part in and overlapping with each other that are responsible for the failure rate.

Technical errors are responsible for both early failure and revision of failed ACL reconstruction surgery (21). Kamath et al. (5)reported that technical error was identified as a cause of failure in 22–79% of their cases. In the present study, we have found a considerable rate of technical error, precisely tunnel malposition in 40.9% of traumatic cases. Therefore, a traumatic event could not be considered as a unique cause of failure, and there may be a combination of different factors responsible for ACL failure.

We could place emphasis on the importance of mechanical malalignment in ACL-deficient knees as a potential cause of ACL failure. There is obvious indication in the literature to address the mechanical malalignment in ACL-deficient knees with secondary varus knee (varus thrust) (22)and with primary varus knee associated with medial compartment osteoarthritis (23). However, there is a debate in the literature regarding whether to address the abnormal bone morphology in primary varus knee without arthritis. In the present study, we have 3 cases of mechanical malalignment, with 2 of them having a lateral tibial slope of more than 12 degrees; one case had double varus knee. Additionally, neither technical errors nor traumatic events were reported in their history or apparent varus thrust on examination at index surgery. However, we evaluated all the patients clinically to detect resultant rotational instability and radiologically through stress and weight-bearing views to identify the possibility of associated ligament injuries, especially when the clinical examination was inconclusive, and to detect the presence of any mechanical misalignment. The MARS group reported that malalignment was detected as a cause of failure in 4% of cases (9). Noyes and Barber-Westin reported that coronal malalignment more than 5 degrees was rated as a cause of failure in 25% of cases (24). While Kim et al. found that there is no difference in the outcomes of patients undergoing primary ACL reconstruction with primary varus knee (25). Therefore, the literature could be inconclusive regarding the impact of coronal malaligment or elaborate the type of malalignment in ACL reconstruction surgery. However, many studies have placed more emphasis on the importance of sagittal tibial morphology increasing the strain over the reconstructed ACL and it was significant with steeper medial or lateral tibial slope of 12 degrees or more (26). Therefore, we had three failed cases due to mechanical malalignment either due to varus or higher tibial slope.

Gersoff and Clancy reported the association of posterolateral corner (PLC) injury and ACL injury as 10bial (27). However, the diagnosis of PLC injury is sometimes challenging, and if it is left untreated, it will increase the stress over the reconstructed ACL graft with subsequent early graft failure. Stress varus views are considered a reliable method for objective evaluation of existence of associated PLC injury. LaPrade et al. (28),(28)TION 28 \l 1033 sis of PLC injury is sometimes challenging, and if it is left untreated, it will increase the stress over the reconstructed ACL graft with subsequent early graft failure. Stress varus views are considered a reliable method for o suggestive of a complete PLC injury. We had 3 missed cases of PLC/FCL, and for all of them, the ACL reconstruction was carried out shortly after injury. However, in clinical practice, the varus stress view is not without limitations, as some patients can express guarding or fail to relax in the face of acute injury, making a valid objective measurement impossible.

In the absence of technical errors or traumatic mechanisms, failed ACL reconstruction is due to biological causes, as the graft failed to incorporate and can't withstand excessive loads or repetitive stress without revascularization (29)It is known that the graft is exposed to a long biologic process starting with graft necrosis, revascularization, cellular proliferation with collagen deposition and ending with remodelling, a process called ligamentization (30). An insult to the graft during this process, especially in the early necrotic phase, by infection, immune response, repetitive trauma and aggressive rehabilitation may result in early graft failure (31) (32).

It should be kept in mind that there was a risk of graft slippage due to failed fixation, which could appear as a lax graft arthroscopically, but this was not the case in the traumatic group where the pattern of rupture was different. Indeed, this could be explained by anatomical ACL reconstruction, although it is still not isometric. The isometricity will increase dramatically in the presence of an aberrant graft position due to tunnel malposition or excessive graft stress due to bony morphology or associated non-reconstructed ligaments leaving the graft with cycling load and tear/microtear injury during ligamentization, which eventually resulted in an elongated healed failed graft. However, further clarification of the mode of graft failure is beyond the scope of this article.

Limitations of this study include a relatively small number of patients and being performed retrospectively. We assume that the actual incidence of failure might be more, as some patients could be missing their follow-up due to many reasons, including revision elsewhere outside our institution. Another limitation could be the homogeneity of the revised cases in term of their sex, although we have operated on many female patients, including professional athletes, with no failed cases among them. This could be explained by a relatively very small number of female cases being operated on as compared to male cases. Additionally, many confounders may be omitted in this study, such as ACL reconstructed knee with deficit menisci, Generalised joint hypermobility, being overweight and age. We could not realize how patients with hyperlaxity or knees with deficits of the medial meniscus could behave with ACL reconstruction or how they could impact knee stability, especially in the absence of control cases. Although we have delineated the definition of failure, there is no general agreement among the literature on which we could rely on. Moreover, the incidence of technical errors in successful ACL reconstruction cases and favouring one graft fixation over the other might be difficult in the absence of acontrol group.
We understand this present study is small relative to the number of cases and the incidence rate might be under-reported among studies. However, the incidence could vary or increase according to the criteria for the definition of failure given as recurrent swelling, pain, and loss of some range of motion, which could persist in what we consider successful ACL reconstruction. Nevertheless, we set the criteria to necessitate ACL revision rather than ACL reconstruction with lower outcomes. As a result, this study tries to analyse variable potential causes leading to ACL failure that entail revision and add to the flourishing growing body of ACL reconstruction surgery.

CONCLUSION

This present study elaborated what is stated in many studies and detected non-traumatic causes in the majority of failed cases (59.3%) with a failure incidence rate of 5.8%. The aetiologies behind ACL failure could be multifactorial, and the causes might not exclude each other reciprocally. Despite the improvement in surgical techniques, fixation devices, and attention to the anatomy of the ACL footprint, the incidence of failure is still in the same range. We believe that the successful systematic approach starts with the establishment of a universally accepted definition of failure and interpretation of all the potential causes, which might eventually decrease the incidence.

Funding: There is no funding source.

Conflict of interest: The authors declare that they have no conflict of interest.

REFERENCES

1. **Engelman GH, Carry PM, Hitt KG, Polousky JD, Vidal AF**. Comparison of allograft versus autograft anterior cruciate ligament reconstruction graft survival in an active adolescent cohort. Am J Sports Med. 2014;42:2311-8
2. **Freedman KB, D'Amato MJ, Nedeff DD, Kaz A, Bach BR Jr.** Arthroscopic anterior cruciate ligament reconstruction: a metaanalysis comparing patellar tendon and hamstring tendon autografts. Am J Sports Med. 2003;31:2-11
3. **Adriani E, Summa P, Di Paola B.** Pre-operative planning in anterior cruciate ligament reconstruction revision surgery. Joints. 2013;1:25-33.
4. **Shybut TB, Pahk B, Hall G, Meislin RJ, Rokito AS, Rosen J, Jazrawi LM, Sherman OH**. Functional outcomes of anterior cruciate ligament reconstruction with tibialis anterior allograft. Bull Hosp Jt Dis 2013;71(2):138–143.
5. **Kamath GV, Redfern JC, Greis PE, Burks RT.** Revision anterior cruciate ligament reconstruction. Am J Sports Med 2011;39(1):199–217. https://doi.org/10.1177/0363546510370929.
6. **Lind M, Menhert F, Pedersen AB.** Incidence and outcome after revision anterior cruciate ligament reconstruction: results from the Danish registry for knee ligament reconstructions. Am J Sports Med 2012;40(7):1551–1557.
7. **van Eck CF, Schkrohowsky JG, Working ZM, Irrgang JJ, Fu FH.** Prospective analysis of failure rate and predictors of failure after anatomic anterior cruciate ligament reconstruction with allograft. Am J Sports Med 2012;40(4):800–807.
8. **MARS Group.** Effect of graft choice on the outcome of revision anterior cruciate ligament reconstruction in the Multicenter ACL Revision Study (MARS) Cohort. Am J Sports Med 2014;42(10):2301–2310. https://doi.org/10.1177/0363546514549005.
9. **MARS Group, Wright RW, Huston LJ, Spindler KP, Dunn WR, Haas AK, Allen CR, Cooper DE, DeBerardino TM, Lantz BB, Mann BJ, Stuart MJ.** Descriptive epidemiology of the Multicenter ACL Revision Study (MARS) cohort. Am J Sports Med 2010;38(10):1979–1986. https://doi.org/10.1177/0363546510378645.
10. **Brophy RH, Haas AK, Huston LJ, Nwosu SK, Group M, Wright RW.** Association of meniscal status, lower extremity alignment, and body mass index with chondrosis at revision anterior cruciate ligament reconstruction. Am J Sports Med 2015;43(7):1616–1622. https://doi.org/10.1177/0363546515578838.
11. **Hashemi J, Chandrashekar N, Mansouri H, Gill B, Slauterbeck JR, Schutt RC Jr, Dabezies E, Beynnon BD.** Shallow medial tibial plateau and steep medial and lateral tibial slopes: new risk factors for anterior cruciate ligament injuries. Am J Sports Med 2010; 38(1):54–62. https://doi.org/10.1177/0363546509349055.
12. **Hudek R, Fuchs B, Regenfelder F, Koch PP.** Is noncontact ACL injury associated with the posterior tibial and meniscal slope? Clin Orthop Relat Res 2011;469(8):2377–2384. https://doi.org/10.1007/s11999-011-1802-5.
13. **Ireland ML, Ballantyne BT, Little K, McClay IS.** A radiographic analysis of the relationship between the size and shape of the intercondylar notch and anterior cruciate ligament injury. Knee Surg Sports Traumatol Arthrosc 2001;9(4):200–205. https://doi.org/10.1007/s001670100197.
14. **Matava MJ, Arciero RA, Baumgarten KM, Carey JL, DeBerardino TM, Hame SL, Hannafin JA, Miller BS, Nissen CW, Taft TN, Wolf BR, Wright RW, MARS Group.** Multirater agreement of the causes of anterior cruciate ligament reconstruction failure: a radiographic and video analysis of the MARS cohort. Am J Sports Med 2015;43(2):310–319. https://doi.org/10.1177/0363546514560880.

15. **Dejour D, Ntagiopoulos PG, Saggin PR, Panisset JC.** The diagnostic value of clinical tests, magnetic resonance imaging, and instrumented laxity in the differentiation of complete versus partial anterior cruciate ligament tears. Arthroscopy 2013;29(3):491–499. https://doi.org/10.1016/j.arthro.2012.10.013.
16. **Irrgang JJ, Ho H, Harner CD, Fu FH.** Use of the international knee documentation committee guidelines to assess outcome following anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 1998;6(2):107–114. https://doi.org/10.1007/s001670050082.
17. **Irrgang JJ, Anderson AF, Boland AL, Harner CD, Kurosaka M, Neyret P, Richmond JC, Shelborne KD.** Development and validation of the International Knee Documentation Committee Subjective Knee Form. Am J Sports Med 2001;29(5):600–613. 1
18. **Bernard M, Hertel P, Hornung H, Cierpinski T.** Femoral insertion of the ACL. Radiographic quadrant method. Am J Knee Surg 1997;10(1):14–21.
19. **Staubli HU, Rauschning W.** Tibial attachment area of the anterior cruciate ligament in the extended knee position. Anatomy and cryosections in vitro complemented by magnetic resonance arthrography in vivo. Knee Surg Sports Traumatol Arthrosc 1994;2(3):138–146.
20. **Alyamani A, Mustapha A, Aljazzazi M, Odat M, Ghnaimat M.** Acceptance, reliability and validity of the Arabic version of Lysholm Knee Score. J Roy Med Serv 2017;24(3):6-12.
21. **Colosimo AJ, Heidt RS Jr, Traub JA, Carlonas RL.** Revision anterior cruciate ligament reconstruction with areharvested ipsilateral patellar tendon. Am J Sports Med 2001;29(6):746–750.
22. **Badhe NP, Forster IW.** High tibial osteotomy in knee instability: the rationale of treatment and early results. Knee Surg Sports Traumatol Arthrosc 2002;10(1):38–43.
23. **Kean CO, Birmingham TB, Garland JS, Jenkyn TR, Ivanova TD, Jones IC, Giffin RJ.** Moments and muscle activity after high tibial osteotomy and anterior cruciate ligament reconstruction. Med Sci Sports Exerc 2009;41(3):612–619.
24. **Noyes FR, Barber-Westin SD.** Anterior cruciate ligament revision reconstruction: results using a quadriceps tendon-patellar bone autograft. Am J Sports Med 2006;34(4):553–564.
25. **Kim SJ, Moon HK, Chun YM, Chang WH, Kim SG.** Is correctional osteotomy crucial in primary varus knees undergoing anterior cruciate ligament reconstruction? Clin Orthop Relat Res 2011;469(5):1421–1426.
26. **Webb JM, Salmon LJ, Leclerc E, Pinczewski LA, Roe JP.** Posterior tibial slope and further anterior cruciate ligament injuries in the anterior cruciate ligament–reconstructed patient. Am J Sports Med 2013;41(12):2800–2804.
27. **Gersoff WK, Clancy WG Jr.** Diagnosis of acute and chronic anterior cruciate ligament tears. Clin Sports Med 1988;7(4):727–738.
28. **LaPrade RF, Heikes C, Bakker AJ, Jakobsen RB.** The reproducibility and repeatability of varus stress radiographs in the assessment of isolated fibular collateral ligament and grade-III posterolateral knee injuries: an in vitro biomechanical study. J Bone Joint Surg Am 2008;90(10):2069–2076.
29. **Maday MG, Harner CD, Fu FH.** Revision ACL surgery: evaluation and treatment. The crucial ligaments. In: Feagin JA, editor. Diagnosis and treatment of ligamentous injuries about the knee. 2nd New York: Churchill-Livingstone; 1994. pp. 711–723.
30. **Corsetti JR, Jackson DW.** Failure of anterior cruciate ligament reconstruction: the biologic basis. Clin Orthop Relat Res 1996; (325):42–49.
31. **Arnoczky SP.** Biology of ACL reconstructions: what happens to the graft? Instr Course Lect 1996;45:229–233. 28
32. **Muneta T, Yamamoto H, Takakuda K, Sakai H, Furuya K.** Effects of postoperative immobilization on the reconstructed anterior cruciate ligament. An experimental study in rabbits. Am J Sports Med 1993;21(2):305–313.