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Recognizing the better autograft and the factors influencing outcomes of revision anterior cruciate ligament reconstruction

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ABSTRACT

Objectives: The outcome of revision anterior cruciate ligament reconstruction (ACLR) is inferior to that of the primary reconstruction and is influenced by multiple factors. The purpose of this study was to identify the better autograft suited for revision ACLR and to assess the factors influencing the outcome of revision.

Methods: A total of 102 patients who underwent revision ACLR were enrolled in this study. The patients were grouped based on the type of autograft used for revision. The mechanism of injury and the cause of the primary ACLR failure, meniscal, and chondral status were noted. All patients' Tegner Lysholm functional scores were assessed at 2 years of follow-up.

Results: Almost 37.3% of the patients underwent revision ACLR with bone-patellar tendon bone, 41.3% with semitendinosus-gracilis, and 21.3% with quadriceps tendon autografts. The mean Tegner-Lysholm score was 85.4 ± 15.8, with the majority achieving good to excellent scores. Chondral defect of Grade 3/4 was associated with an inferior poorer functional outcome (P = 0.03). At a 2-year follow-up, the non-contact mechanism of primary ACLR failure was associated with worse scores compared to the contact mechanism of failure (P = 0.03). On comparison of Lysholm functional score between different autografts using the Kruskal-Wallis test, the p-value was insignificant (P = 0.9).

Conclusion: Non-contact mechanism of primary ACLR failure and Grade 3/4 chondral defects was associated with a poorer functional outcome at 2 years post-revision ACLR. The overall functional outcome of revision ACLR was good to excellent in our Middle East Asian population, with no one autograft found to be superior to the other.

Keywords: Anterior cruciate ligament reconstruction, Autografts, Contact, Non-contact, Oman, Revision

INTRODUCTION

Of all anterior cruciate ligament reconstructions (ACLRs), around 5.4% of patients undergo revision surgery in <5 years and revision ACLR accounts for 10% of the total number of ACLRs performed.[1,2] Increasing number of people are keen on pursuing an active lifestyle post-ACLR, hence resulting in a greater demand for an improved quality of life and satisfaction post-revision ACLR. However, the results of revision ACLR are less compared to those of the primary ACLR.[3,4] The Scandinavian knee ligament register and Swedish national anterior cruciate register both

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reported significantly low clinical scores and poor patient-reported quality outcomes after revision ACLR.[5,6] Although the previous studies have analyzed the outcome of revision ACLR in Western populations, no studies have focused on the Middle East Asian population with their unique daily needs like kneeling, where high knee flexion is required.[3-6] Autografts, especially bone-patellar tendon-bone (BPTB), are known to be associated with an increased incidence of kneeling pain, anterior knee pain, and so are quadriceps tendon (QT), semitendinosus-gracilis (STG) autografts influencing functional satisfaction.[7-9] Thus, identifying the better-suited autograft for revision ACLR with superior functional outcomes is important.

Factors influencing the outcome of primary ACLR are well established. Age, mechanism of failure, delay in surgery, and associated chondral defects are reported to impact the functional outcome of ACLR.[10-12] However, it is worth studying if the same holds true for the revision ACLR outcome. We hypothesized that the mechanism of injury, associated chondral defects, and increased time duration between primary and revision surgeries would adversely impact the outcome of revision ACLR.

The present study had two purposes, the first one was to identify the better autograft for revision ACLR and the second was to study the effect of influencing factors on the functional outcome of revision ACLR in a Middle East Omani population.

MATERIALS AND METHODS

All the patients who underwent revision ACLR at our tertiary care center for Sultanate of Oman from 2015 to 2018 were identified in our local database and retrospectively reviewed. The ACL graft failure after primary reconstruction surgery was confirmed based on clinical and radiological examination with MRI. In addition, the medical records were reviewed to identify the gender, side, mechanism of primary ACLR failure due to contact versus non-contact injury, gap between the primary and the revision surgeries, choice of graft for primary and revision reconstruction, and associated injuries.

The failure mechanism was classified as contact and non-contact based on the Hunt Valley II meeting.[13] Contact failure was defined as a failure after the patient's knee or body came in contact with an external force (e.g., another person or object). Non-contact failure was defined as failure due to twist, sprain, jumping, or landing but without direct physical contact with other people or stationary objects. If the failure mechanism was not recorded, the patient was interviewed in detail to collect the necessary information regarding the failure before the revision surgery.

The operative notes of the revision surgery were reviewed to record the associated meniscal status, articular chondral status, the condition of failed neograft, the tunnel position, type, site, and size of the revision graft. Failure due to technical errors was identified preoperatively and confirmed intraoperatively by the surgeon using available evidence (history, physical examination, radiographs, MR images, and arthroscopic evaluation). Technical errors like malpositioned tunnel requiring tunnel revision with or without bone graft and failure of implants were identified and recorded. The patient's functional outcome of the revision ACLR was assessed at 2 years postoperatively using the Tegner Lysholm knee score.

The inclusion criteria were patients who underwent revision ACLR in a single stage with autografts at our center by two fellowship-trained senior surgeons (SG and MR) who also determined the Outerbridge classification of chondral lesions intraoperatively, tunnel position, and neograft status. The patients who underwent more than 1 revision, meniscal repair, or previous lower limb surgeries were not included in the study. Subjects with inflammatory diseases, coexisting multi-ligament injuries, lower limb malalignment same or contralateral side, those who underwent concomitant ligamentous reconstruction, meniscal repair for tears, microfracture for chondral lesions, or alignment correction surgery were excluded from the study. Failures due to infection requiring revision surgery and patients lost for follow-up were also excluded from the study. The study enrolled 102 patients who underwent revision ACLR with STG, BPTB, or QT autografts.

Surgical technique

All the patients underwent revision ACLR using autografts, either STG, BPTB, or QT, based on the patient's preference depending on the previously used graft after explaining the pros and cons of each type of autograft. All surgeries were performed using all endoscopic, arthroscopic assisted with femoral tunnel drilled using the trans-portal technique. Fixation of all patellar tendon grafts was done with interference screws. Hamstring and quadriceps fixation was variable, utilizing staples, an interference screw, and Endobutton techniques utilized based on the surgeon's preference.

Rehabilitation

Subjects in the study underwent a common institutional rehabilitation protocol post the revision ACLR. All the groups of patients were allowed a full passive range of motion after surgery. Early emphasis was placed on patellar and extensor mechanism mobility to prevent stiffness and scarring. Physical therapy commenced 24 h after surgery to gain an early range of motion and muscle reactivation and control edema. Rehabilitation included straight-leg raises in

an immobilizer until the patient was able to perform them without any extension lag.

Partial weight-bearing was allowed for 2 weeks, with general weight-bearing at 6 weeks. Squats and single-leg exercises were started at 8 weeks, with supervised sports-specific exercises at 20 weeks after the quadriceps strength normalized post-revision.

Clearance for full competitive activity was based on successful completion of the knee sports test at 6 months postoperatively.

Statistical analysis

Data were tested for normal distribution using the Kolmogorov–Smirnov Z-test and found to be not normally distributed. The data analysis was done using a non-parametric approach. Comparison of functional outcome of different autografts was performed using Kruskal–Wallis test. The association between the functional outcome and mechanism of failure, chondral status, the side affected, and technical errors of failure was assessed using the Mann–Whitney U-test. Spearman's rho correlation coefficient was used to determine the linear correlation between the duration of time between surgeries and the outcome. All statistical analyses were performed using commercially available software (SPSS version 25, IBM, Armonk, NY), with $P < 0.05$ considered statistically significant.

RESULTS

The study included 75 patients out of the total 102 enrolled, with one patient excluded due to infection failure, three for having more than 1 revision surgery, nine patients had associated ligamental injuries, and 14 were lost to follow-up. All the enrolled patients were male, providing a homogenous population with a mean age of 29 years (range 24–47 years). The demography of the study population with the primary, revision autograft distribution and functional score is listed in [Table 1]. STG was the most chosen graft for primary and revision surgeries. The majority of the patients (71%) reported good-to-excellent functional outcomes at 2 years following the revision. However, technical errors accounted for 22% of the revision surgeries, with femoral tunnel malposition being the most common based on the pre-operative radiograph, computed tomography imaging, and intraoperative assessment by operating surgeon [Table 1]. All the revision surgeries performed were single staged with no additional bone grafting required for tunnel revision.

The different autografts used were similar in their functional outcome when compared using the Kruskal–Wallis test with $P = 0.9$. However, 40 patients (53.3%) had associated meniscal injuries, of which 11 (27.5%) of them underwent partial meniscectomy at the time of revision [Table 2]. Intraoperatively, 14 patients were found to have a lax primary ACL graft, five had a partial tear, and the rest had fully torn ACL (56) during the revision surgery. The lax and partially torn ACL graft was noted only in those patients with hamstrings as a primary graft. One-quarter of the sample, 25.3% (19), of the study population, were recorded with Outerbridge articular cartilage Grade 3–4. The STG graft during the revision ACLR was found to be the thinnest compared to the rest of the autografts [Table 2].

Almost 70% of the failed primary ACLRs were due to contact mechanisms in our study group. There was a significant difference between the contact and non-contact mechanism of the failure groups in the Tegner-Lysholm score with $P = 0.03$ (<0.05). The non-contact failure patients had poorer functional scores compared to the contact failure group [Table 3]. The Mann–Whitney U-test had $P = 0.36$, which

Table 1: Demographic description of the study population.

Variable	Summary of statistics
Age	29 years (24–47 years)
Gender (M/F)	75/0
Interval between surgeries	54.7 months (range 9–228 months)
Tegner Lysholm score	85.4±15.8 (range 37–100)
Excellent (>90)	38 (50.6%)
Good (84–90)	16 (21.3%)
Fair (65–83)	11 (14.6%)
Poor (<65)	10 (13.3%)
Primary autografts	
BPTB	7 (9.3%)
STG	68 (90.6%)
Revision autografts	
BPTB	28 (37.3%)
STG	31 (41.3%)
QT	16 (21.3%)
Technical errors	
Femoral tunnel malposition	16 (94.1%)
Implant (Endobutton) failure	1 (5.9%)

M: Male, F: Female, R: Right, L: Left, ACLR: Anterior cruciate ligament reconstruction, BPTB: Bone-patellar tendon-bone, STG: Semitendinosus gracilis, QT: Quadriceps tendon

Table 2: Distribution of score and operative findings of autografts.

	BPTB (28)	STG (31)	QT (16)
Tegner Lysholm score (mean+SD)	85.9±15.6	83.9±18.4	87.4±10.5
Grades 3–4 chondral defect	8	9	2
Meniscal tear	13	9	7
Meniscectomy	3	6	2
Thickness of revision graft	9.8±0.7	8.4±0.8	9.6±0.8

BPTB: Bone-patellar tendon-bone, STG: Semitendinosus gracilis, QT: Quadriceps tendon

Table 3: The association of factors with functional outcome using the Mann–Whitney U-test.

Mechanism of failure	**53 (contact)**	**22 (non-contact)**	***P*=0.035**
Side	50 (right)	25 (left)	*P*=0.36
Chondral status	**56 (Grades 0–2)**	**19 (Grades 3–4)**	***P*=0.036**
Cause of failure	17 (technical)	58 (non-technical)	*P*=0.6

did not show an association between the side effects. The failure group due to technical errors included malpositioned femoral tunnel required tunnel revision had no association with functional outcome (P = 0.6). A significant association was found between the functional scores and the Outerbridge Grade 3–4 chondral defects, which had a poorer score compared to those who did not have Outerbridge Grade 3–4 chondral defects (P = 0.036) [Table 3]. The time between the primary and revision ACLR (range 9–228 months) was not correlated, with the functional outcomes on the Spearman rho correlation test (P = 0.6).

DISCUSSION

The choice of graft is controversial not only in primary ACLR, but more so in revision ACLR surgeries because of the limited graft options.[14] The superior autograft for revision ACLR remains, a topic of debate as seen in primary ACLR.[2,14] To the best of our knowledge, no previous studies have examined the autograft with better functional outcomes in our Omani Middle East Asian population. Our population's functional demands are different as they perform high flexion knee functional activities, such as kneeling, squatting for prayers, and social customs, for prolonged durations. For example, an individual following the Islamic practices is expected to pray 5 times a day and may regularly flex their knees as often as 70 times/day, with their knees fully flexed up to 150–165°.[15-17] This degree of flexion exceeds that found in the population without kneeling customs by an average of 15°.[15-17] Donor site morbidity is an important deciding factor in patient satisfaction, who routinely kneel as in our study group. The BPTB autograft is well known to be associated with anterior knee pain and patellofemoral symptoms affecting kneeling activities.[18] Patients reported inferior short- and long-term outcomes after revision ACLR with BPTB grafts.[19] Quadriceps tendon and hamstring being the most preferred autograft for revision, both are reported to be associated with anterior knee pain and donor site morbidity influencing the functional outcome.[2,20,21] The literature is limited in terms of comparison of the autografts in revision ACLR. However, the QT graft is reported to have a better functional Lysholm score in comparison to both the STG and BPTB in primary ACLR.[22,23] In our study of revision ACLR, we found the functional score of three different autografts to be comparable, despite the higher functional requirements of our population.

Non-contact mechanism of failure is the most common cause accounting for almost 70% of the ACL injuries, with females reported to have a 2–8-fold greater risk of ACL failure due to the non-contact mechanism.[12,13,24,25] However, in our study of failed primary ACLR, all recorded patients were male. Our study's failure due to contact mechanism accounted for 70%, contrary to the published studies of failure mechanism in native ACL.[26,27] One of the most important findings of this study was the association of inferior functional outcomes of revision ACLR with the non-contact mechanism of failure. To the best of our knowledge, no study in the literature has studied the effect of the mechanism of failure of primary ACLR on the functional outcomes of revision ACL surgeries. Our study is a short-term follow-up of 2 years, and thus, there is a need for a study on long-term follow-up.

The Outerbridge grading system of chondral defects has been proven to have some prognostic value with a reported to have fair to substantial inter-and intra-observer agreement between experienced surgeons.[28] Sofu *et al.* reported the prediction of clinical outcome of primary ACL reconstruction based on the chondral grading.[29] They observed that the Grade 3/4 chondral lesions have poorer visual analog and Lysholm scores.[29] The results of this study were similar in the revision ACLR cases with a worse functional score in higher graded lesions compared to Grades 0–2. Our hypothesis was increased duration between surgeries would be associated with poorer functional outcomes after revision. On the contrary, we observed no association between them. Therefore, the knowledge of the existence of chondral defects and the failure mechanism may help predict the functional outcome following revision, which would greatly benefit the patient's prepping and counseling.

Technical errors in our study, including the failed primary ACLR, which were operated in other hospitals, accounted for 22% of the failed primary reconstruction, similar to the 24% reported in the MARS study.[30] The literature reported that femoral tunnel malposition was the most common technical error.[2,30] The patient-related outcomes between a single-stage and two-stage surgery with a tunnel revision are reported to be similar.[31] However, we found no evidence in the literature regarding the outcome in patients who underwent revision of femoral tunnel in a single-stage revision ACLR. Our study reports comparable functional outcomes in revision ACLR irrespective of revised tunnel position. In combination with the results of our study, these findings suggest that surgeons should discuss the possibility of good functional outcomes in patients irrespective of femoral tunnel revision.

LIMITATIONS

Our study was a retrospective review and, as such, has an inherent bias. In addition, for the mechanism of injury, we relied on the patient's history, which possibly could cause recall bias. Although, we believe that the recall bias would be lesser in patients with the second failure than in the primaries. Another limitation was that the autograft choice for revision was not randomized. The third limitation of the study is that no pre-operative/post-operative scores during specific activities like praying were available for comparison. Therefore, a study with a large population and a longer follow-up is required.

CONCLUSION

Non-contact mechanism of primary ACLR failure and Grade 3/4 chondral defects was associated with poorer functional outcomes at 2 years post-revision ACLR. On the other hand, the functional outcomes of revision ACLR were good to excellent in our Middle East Asian population, with no one autograft (STG, BPTB, and QT) found to be superior to the other.

RECOMMENDATIONS

Revision ACLR should involve thorough pre-operative history, workup, and planning. These cases should be handled at tertiary level centers by experienced surgeons with consideration of the multiple factors to provide an accurate prognosis on the functional outcome following revision. We also recommend future studies to compare the functional outcomes of revision ACLR with a control group after primary ACLR.

AUTHORS' CONTRIBUTIONS

SS conceived and designed the article's outlines, data collection, and prepared the initial draft. IS and SA contributed to data collection and SM contributed to the statistical analysis. SG and MR prepared the final draft. All authors have critically reviewed and approved the final draft and are responsible for the manuscript's content and similarity index.

ETHICAL APPROVAL

Ethical approval was obtained from the Khoula Hospital research ethical committee (PRO112020113) on November 26, 2020.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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