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The Development and Early to Mid-Term Findings of the Multicenter Revision ACL Study (MARS)

MARS Group

Introduction

Injuries to the anterior cruciate ligament (ACL) are common, with approximately 200,000 ruptures occurring in the United States each year.[1, 2] ACL reconstruction is recommended

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in those patients who desire a return to jumping, cutting and pivoting activity. While the majority of patients will experience restored knee stability and function with primary ACL reconstruction, failure continues to be seen in a small, but significant, percentage of patients. Modern day failure rates have been reported to range between 3% and 13%, despite improvement in surgical technique and understanding of ACL injury and rehabilitation.[3–6] Potential causes for poor outcome include loss of motion, extensor dysfunction, arthritis and recurrent instability; the latter of which often requires revision ACL reconstruction. Failure of primary ACL reconstruction presents a series of unique challenges for both the surgeon and patient. Revision ACL reconstruction is often technically more difficult, and patients often present with an increased rate of concomitant intra articular damage to the knee.[7, 8] Patient reported outcomes following revision reconstruction are also consistently inferior to outcomes reported following primary reconstruction.[6, 9–11]

Making of the MARS Study

The impact of failure of primary ACL reconstruction is significant. Multiple studies demonstrate previous graft failure to be the strongest predictor of poor postoperative outcome.[6, 9–11] Developed with the support of the American Academy of Sport Medicine Surgeons (AOSSM), the Multi-Center ACL Revision Study (MARS) was established to analyze patients undergoing revision reconstruction, identify factors contributing to primary graft failure and report on outcomes following revision surgery. Previous studies reporting on revision ACL reconstruction focused primarily on surgical technique and were limited by small numbers of patients and low level of evidence.[11–14] In contrast, the MARS study would prospectively analyze data from a relatively large population of patients to identify technical, biologic and patient driven contributions to graft failure, in addition to reporting on post-revision patient reported outcome. The data generated would not only have the potential to alter the technical aspects of ACL reconstruction and postoperative rehabilitation, but also provide valuable prognostic information with which to improve patient counseling regarding realistic expectations following revision ACL reconstruction.

Study Design and Recruitment of Participating Surgeons

Revision reconstructions make up less than 10% of all ACL reconstructions performed by an average sports surgeon each year.[9, 10] In an effort to achieve the number of study participants necessary for the desired analysis, MARS was developed utilizing a multi-center design. An a priori power analysis determined that approximately 1000 study patients would be required to analyze the 75 selected independent variables (10–15 study participants per variable). It was also estimated that 50–75 participating surgeons would be required. Participation in the MARS study was offered to all active members of AOSSM. For inclusion in the study each surgeon was required to obtain and maintain Institutional Review Board (IRB) approval from his or her own institution. Surgeons were also required to complete training sessions regarding the study design and data collection, including specific standardized criteria for grading articular cartilage and meniscal status. Surgeons were instructed to perform revision ACL reconstruction according to their own practice preference; however if allograft tissue was utilized, it was required that the graft be obtained from Musculoskeletal Transplant Foundation.

The MARS Surgeons and Study Cohort

Final study participation included 83 surgeons, from 52 independent clinical sites, representing all geographic regions of the United States. Private and academic clinical practice settings were equally represented among participating sites. Study enrollment began in 2006 and concluded in 2011. All patients undergoing revision ACL reconstruction were eligible for inclusion and offered study participation. Patients with operative multi-ligamentous knee injuries were excluded. A total of 1205 patients were enrolled in the study. Among these patient 58% (695) were males. The median age was 26 years (range 12–63).

Data Collection

Preoperatively patients completed questionnaires detailing basic demographic information, type of sport and level of participation, mechanism of injury, medical comorbidities and previous history of knee injury. Patients also completed baseline outcome scores validated for evaluation of injury/dysfunction specific to the knee. These outcome scores included the Knee Injury and Osteoarthritis Outcome Score (KOOS), the International Knee Documentation Committee Subjective form (IKDC), the Western Ontario and McMasters Universities Arthritis Index (WOMAC), the Short Form Health Survey (SF-36) and the Marx activity rating scale. All patients underwent preoperative clinical evaluation by participating surgeons. A standard radiographic series was obtained on all patients and included bilateral standing anterior-posterior knee view, bilateral bent knee Rosenberg posterior-anterior view, bilateral merchant view, a hyperextension lateral and a standing long-leg alignment view. Surgeons completed questionnaires detailing the findings of physical and radiographic examination and the suspected etiology of failure. Following surgery, the surgeons documented the revision technique utilized, the intra-articular findings and surgical management of meniscal and chondral damage. Chondral damage was classified using the modified Outerbridge system.[15] In the setting of meniscal injury, the location and severity (partial versus complete) of the tear was documented along with the type of treatment (repair versus partial meniscectomy). Patients were contacted two years following revision surgery. Repeat SF-36, IKDC, KOOS, WOMAC and Marx Activity outcome scores were completed via mail and telephone surveys were performed to determine if patients had had subsequent surgery on either knee since the revision. In the setting of repeat surgery, operative reports were obtained to determine the reason for treatment and the procedure performed.

Statistical Analysis

The two-year post-operative patient reported outcome scores (IKDC, KOOS and Marx Activity scale) were selected as the primary outcome variables. Multivariable regression analysis was performed to determine which risk factor independently impacted postoperative outcome score. These primary outcome variables were all treated as continuous. The covariates that we controlled for were demographics, previous surgical techniques, current surgical techniques and intra-articular findings. Statistical analysis was performed using open source R statistical software (www.r-project.org; Version 3.0.3).

Descriptive Epidemiology of the MARS Cohort

Early data from the MARS study reported on the descriptive epidemiology of the first 460 enrolled patients.[7] The majority of patients were male (57%) and 86% were undergoing their first revision ACL reconstruction. Repeat trauma was deemed to be the cause of failure in the majority of patients (32%). Seventy-six percent of patients were playing a sport at the time of repeat injury and in 71% the injury occurred in a noncontact setting. The most common sports included soccer (18%), basketball (16%), football (12%) and skiing (8%). Improper surgical technique, most commonly femoral tunnel malposition (80%), was responsible for 24% of failures; 7% were the result of biologic failure. In 37% of patients, a combination of factors (traumatic, technical and biologic) was felt to contribute to failure. The failed grafts included 70% autograft (64% patellar tendon and 34% soft tissue) and 27% allograft (55% patellar tendon and 27% soft tissue). For revision ACL reconstruction the most common graft utilized included patellar tendon autograft (26%), patellar tendon allograft (24%), soft-tissue autograft (22%), and soft-tissue allograft (25%). Six percent of patient required a staged revision reconstruction for bone grafting of dilated tunnels. Fifty-seven percent of patients were noted to have both meniscal and chondral damage at the time of revision surgery. Moderate chondral damage (Outerbridge 2) was seen in 73%. Completely normal articular cartilage and menisci were seen only in 10% of patients.

Radiographic Findings

The standardized preoperative radiographs described above were critically assessed to identify potential factors contributing to failure.[16] Radiographs were reviewed by three independent observers and intraclass correlation coefficients demonstrated high intraobserver agreement (0.7) for the majority of measurements. In more than 42% of patients, the center of the femoral tunnel was found to be greater than 40% anterior to the posterior cortex as measured along Blumensaat's line; a finding indicative of anterior placement of the femoral tunnel. Evidence of graft impingement secondary to improper tibial tunnel placement was noted in 49% of patients.

Impact of Graft Choice on Patient Outcome Following Revision ACL Reconstruction

Graft choice is known to impact the outcome of primary ACL reconstruction.[17, 18] Previous studies have demonstrated 4 times higher odds of graft rupture following allograft reconstruction when compared to autograft reconstruction.[17] In an effort to assess the impact of graft choice in the revision setting, the outcomes of 1205 MARS study patients were evaluated at a median time of 3.4 years from revision reconstruction. Revision reconstruction was performed with autograft tissue in 48%, allograft tissue in 49% and a combination of both autograft and allograft in 3%. Follow-up data was obtained in 1112 patients (92%). All patients reported significant improvement in IKDC and KOOS score compared to baseline ($p < 0.0001$); however, patients reconstructed with autograft tissue demonstrated increased improvement compared to those reconstructed with allograft tissue in the IKDC (OR=1.33 (95% CI: 1.01–1.7)), KOOS Sports and Recreation subscale (OR=1.33 (95% CI: 1.02–1.73), and KOOS Quality of Life subscale (OR=1.33 (95% CI:

1.03–1.73). The Marx activity level score decreased in all patients relative to baseline ($p<0.001$) but was still higher in patients with autograft reconstruction compared to allograft reconstruction ($p=0.012$). The overall rate of graft re-rupture was 3%. Patients reconstructed with autograft tissue were 2.78 times less likely to re-rupture compared to those reconstructed with allograft tissue. For both autograft and allograft, the type of tissue (soft tissue versus patellar tendon) did not impact patient reported outcome or rate of re-rupture.

Factors Contributing to Graft Choice

Graft choice for revision ACL reconstruction can be impacted by a variety of factors including surgeon preference, etiology of failure and previous graft type. Many also argue that graft choice is more limited in the setting of revision reconstruction. Among the 1200 patients in the MARS cohort, revision ACL reconstruction was performed with autograft in 48%, allograft in 49% and a combination of autograft and allograft in 3%.

In a yet to be published study, 83 MARS surgeons were surveyed to determine what factors contributed to the type of graft (autograft versus allograft) selected for revision surgery. Propensity score statistical analysis was then performed to identify factors predicting revision graft type. Individual surgeon preference was found to have the greatest impact on graft choice. Surgeon preference was 5 times more influential than the second most impactful factor, prior graft choice. In patients with a previous autograft failure, allograft was 3.6 more likely to be selected for the revision surgery. Patient age was the third most impactful factor influencing revision graft choice. Older patients were more commonly revised with allograft tissue, whereas autograft tissue was more frequently utilized in younger patients. Other less influential, but still statistically significant, factors impacting graft choice included gender, number of ACL revisions, concurrent repair of the MCL and/or posteromedial capsule and etiology of previous failure. Ultimately the results of this study indicate that the revising surgeon has the greatest impact on graft choice. This finding is clinically significant as graft choice has been shown to independently impact patient outcome, even in the revision setting.

The Impact of Meniscal and Chondral Pathology on Patient Reported Outcome

Revision ACL reconstruction is associated with a higher incidence of pathology involving the menisci and articular cartilage. In a yet to be published study, the independent impact of these associated injuries on patient-reported outcome was analyzed using regression analysis, which was performed controlling for multiple factors such as age, sex, body mass index, activity level, baseline outcomes scores, graft choice and number of ACL reconstructions. Two-year follow-up was obtained in 82% (989/1205) of patients. Patients with a history of prior lateral meniscectomy and those with grade 3 to 4 trochlear chondrosis reported the worst patient outcomes demonstrated by lower IKDC, KOOS and WOMAC scores compared to patients without these findings. Surprisingly, underlying injury to the articular cartilage and/or menisci did not significantly impact patient reported activity level 2 years following revision ACL reconstruction.

Conclusion and Future Directions

Utilizing a multicenter study design, the MARS group has been successful in accumulating a large cohort of patients undergoing a relatively uncommon procedure. The data generated by this study has served to improve our understanding of the challenges associated with revision ACL reconstruction and the factors impacting postoperative outcome. The equal mix of academic and private practice surgeons serves to make the findings generalizable to a broad orthopaedic community. Future studies will focus on the technical aspects of revision ACL reconstruction, such as the impact of issues such as graft fixation, tunnel dilation and tunnel malposition. The impact of postoperative rehabilitation on patient reported 2-year outcome will also be investigated.

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