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Improved results of ACL primary repair in one-part tears with intact synovial coverage

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Abstract

Purpose It was the aim to assess the influence of synovial sheath disruption on early failure of primary anterior cruciate ligament (ACL) repair. It was hypothesized that more-part ACL tears with disruption of the synovial sheath are associated with a higher risk of failure after primary ACL repair.

Methods A cohort study was conducted comprising patients with primal ACL tears undergoing primary ACL repair and dynamic intraligamentary stabilization (DIS). The patients were stratified into three groups: A—one-part rupture with intact synovial membrane ($n=50$), B—two-part ruptures resultant to separation of the ACL into two main bundles with synovial membrane tearing ($n=52$) and C—more parts involving multilacerated ruptures with membrane disruption ($n=22$). Failure was defined as a retear or residual laxity (anterior posterior translation > 5 mm compared to healthy knee). Adjustment for potential risk factors was performed using a multivariate logistic-regression model.

Results The overall failure rate was 17.7% throughout the mean follow-up period of 2.3 ± 0.8 years. The failure rate in patients with one-part ACL tears with an intact synovial membrane was 4% ($n=2$) (Group A), which was significantly lower than the failure rates in groups B and C, 26.9% ($n=14$) ($p=0.001$) and 27.3% ($n=6$) ($p=0.003$), respectively. Disruption of the synovial sheath in two- or more-part tears was identified as an independent factor influencing treatment failure in primary ACL repair (OR 8.9; 95% CI 2.0–40.0).

Conclusion The integrity of the ACL bundles and synovial sheath is a factor that influences the success of ACL repair. This needs to be considered intra-operatively when deciding about repair.

Level of evidence IV.

Keywords ACL repair · Anterior cruciate ligament · Ligamys · Proximal ACL · Proximal tear · Rupture · Tears · Suture · Reconstruction

Introduction

There is increasing evidence in the literature supporting a possible indication for primary repair of the anterior cruciate ligament (ACL) in acute tears [11, 14, 23, 24]. Early published reports tend to show a potential role for primary ACL repair in ACL tears located within the proximal ACL portion [1, 4, 9, 11, 16, 19]. However, despite the increase in scientific activity, evidence is still limited and given the wide range of reported failure rates between 1.8% and 20%, the indication for primary ACL repair is yet to be clearly defined [5, 6, 11, 15, 17]. Identifying the best surgical candidates is likely to limit the outcome ranges to margins of acceptance.

It is also important to emphasize that a variety of different ACL repair techniques, differing in principle, have evolved.

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Some focus on optimizing the biomechanical conditions using a dynamic fixation, which increasingly gives load to the healing ACL, while others purely rely on the biology and sufficient fixation [22].

Dynamic intraligamentary stabilization (DIS) represents one method based on augmenting the proximal repair construct with a polyethylene thread which is then attached to the femur with a button and using a spring device in the proximal tibia [5, 11]. The construct was designed to shield cyclic forces during the healing phase. The results of primary ACL repair using this augmentation construct showed promising results, particularly in proximally located ACL tears (within the proximal third of the ACL) [14, 16].

Given that the synovial membrane with its web-like periligamentous capillaries contributes to the nutritional supply of the ACL [21], it was thought that its integrity may influence the outcome of ACL repair and may need consideration during patient selection. Previous studies analyzed risk factors regarding patient characteristics and rupture location [9, 10, 16]. The influence of rupture pattern on treatment failure has not yet been investigated.

Therefore, the aim of this study was to evaluate whether disruption of the synovial ACL sheath with separation of the underlying ACL fascicles has a significant influence on failure rates after primary ACL repair. It was hypothesized that more-part ACL tears with disruption of the synovial sheath are associated with higher failure rates after primary ACL repair.

Materials and methods

Patients presenting with an ACL tear confirmed by clinical examination as well as magnetic resonance imaging were considered eligible for treatment of ACL repair using DIS if the following criteria were met: acute ACL tear within a 3 weeks' time frame, closed growth plates, side-to-side anteroposterior (AP) translation difference > 5 mm, pre-injury Tegner score of > 4, ACL tear within the proximal third of the ligament confirmed arthroscopically at the beginning of surgery. ACL repair and DIS was not performed with the presence of more than one concomitant ligamentous injury, polytraumatized patients, ACL injuries associated with fractures around the knee, and destroyed non-repairable meniscus.

Cohort description

Between March 2014 and January 2018, 147 consecutive patients with a proximal ACL tear underwent primary ACL repair and DIS augmentation and were followed up in a prospective trial. Fifteen patients were excluded due to short follow-up of < 1 year, and 2 due to insufficient data collection, and 6 were lost to follow-up.

The study group finally consisted of 124 patients (age: 27.7 ± 10.0 years; male: 73; female 51) with a mean follow-up of 2.3 ± 0.8 years (Fig. 1). Primary ACL repair surgery was performed at a mean time of 18.2 ± 9.4 days after the injury. Concomitant meniscal or ligamentous injuries

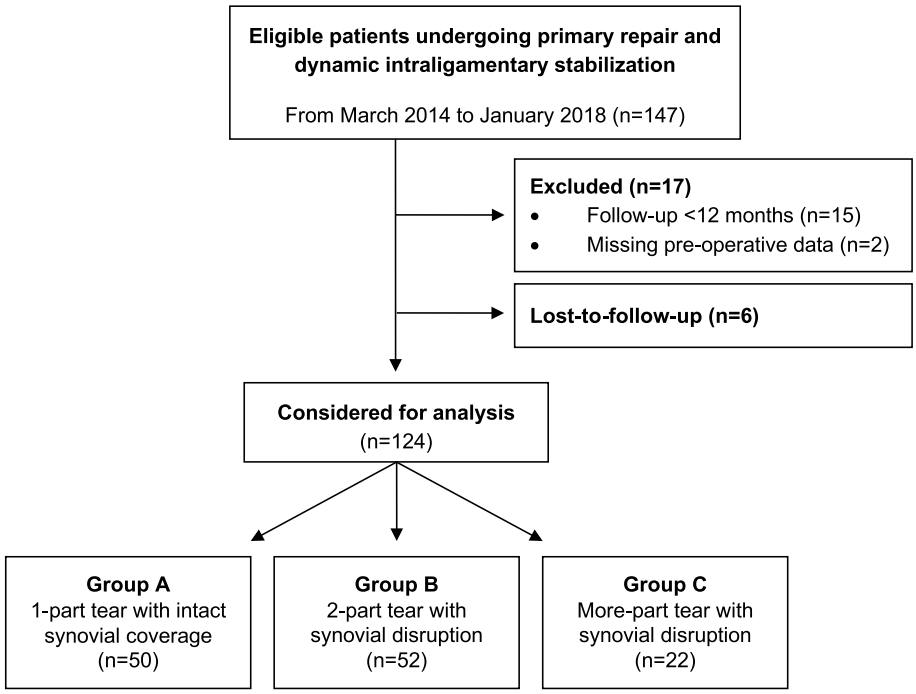

Fig. 1 Flowchart illustrating patients included in the analysis

were found in 58 patients (19 medial collateral ligament (MCL) lesions, of which 15 were augmented according to Ateschrang et al. [2]). Meniscal lesions were found in 39 patients and were either repaired, debrided, or left alone.

Patients were stratified into three groups based on intra-operative assessment of the ACL. Patients with an intact synovial sheath surrounding the torn ACL as a single unit (1-part) were assigned to the first group ($n = 50$) (Group A). Patients with tearing of the synovial sheath were assigned to either group B (2-part) if the ACL was separated into two main parts ($n = 52$) or group C if there was more than a two-part separation (more parts) ($n = 22$). An example of each rupture is illustrated in Fig. 2. The demographics of the three groups are shown in Table 1.

All procedures and post-operative rehabilitation were performed as previously described [1].

Treatment failure was defined as 1—an even associated retear with > 5 mm increase in side-to-side AP translation, or 2—failure to restore joint stability with persistent laxity (side-to-side AP translation of > 5 mm measured) [13].

Post-operative evaluation was conducted at 1 year and 2.5 years after surgery. Side-to-side AP knee translation was measured using the KT-1000 arthrometer (MEDmetric, San Diego, CA, USA) at 30 degrees flexion. The injured and the uninjured knee were both measured three times and a mean was calculated.

The study was approved by the ethical committee of the University of Tübingen (431/2013BO1) and all patients provided written informed consent for participation in the study.

Statistical analysis

A logistic regression model was used for adjustment and structured to define treatment failure as the one end point (output variable), and all previously published risk factors as well as any pre- or peri-operative differences between the groups as input variables for adjustment [9, 16]. Due to the limited number of patients in Group C, only two groups were considered in the analysis to avoid broad confidence intervals, namely Group A vs. all remaining patients. The following variables were also considered in the regression

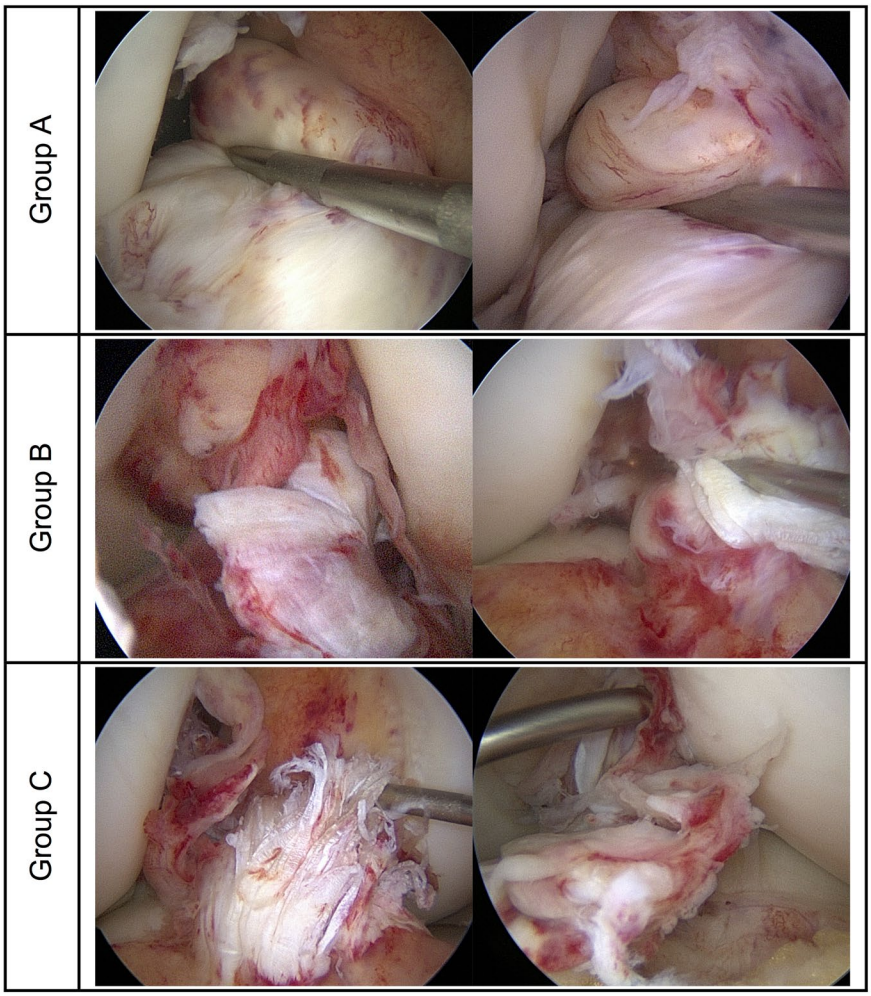

Fig. 2 **a**–**c** Examples of rupture types upon which group assignment was performed. Group A: intact synovial sheath surrounding the torn ACL as a single unit (1-part). Group B: tearing of the synovial sheath and ACL separation into two main parts (2-part). Group C: was more than two-part separation (more parts)

Table 1 Comparison of potential risk factors between groups [mean ± SD (95% CI)]

	Group A—1-part rupture with synovial coverage ($n=50$)	Group B—2-part rupture with synovial disruption ($n=52$)	Group C—> 2-part rupture with synovial disruption ($n=22$)	p value
Anthropometric data				
Age	30.4 ± 10.4 (27.4–33.4)	26.0 ± 9.8 (23.3–28.7)	25.8 ± 8.3 (22.2–29.5)	0.05
Height	175.3 ± 9.3 (172.7-177.7)	175.6 ± 7.6 (173.4-177.7)	174.9 ± 9.1 (170.9–179.0)	n.s
Weight	76.5 ± 13.4 (72.7–80.3)	73.3 ± 13.7 (69.5–77.1)	74.4 ± 15.5 (67.5–81.3)	n.s
Female	21 (42.0%)	21 (40.4%)	9 (40.9%)	n.s
Concomitant ligamentous injuries	8 (16.0%)	10 (19.2%)	1 (14.9%)	n.s
Pre-operative ap. knee instability	7.7 ± 1.8 (7.2–8.2)	8.0 ± 1.6 (7.6–8.5)	7.3 ± 0.9 (6.9–7.7)	n.s
Days from accident to surgery	20.0 ± 11.7 (16.7–23.4)	16.1 ± 6.6 (14.2–17.9)	19.2 ± 8.6 (15.3–23.0)	n.s
Pre-operative sport activity				
Tegner activity level	5 (range 1–9)	5 (range 1–9)	3 (range 1–9)	n.s
Tegner-activity level ≥ 7	7 (14.0%)	14 (26.9%)	5 (22.7%)	n.s
Non-contact sports	33 (66.0%)	24 (46.2%)	12 (54.5%)	n.s

model: age, gender, height, weight, presence of concomitant ligamentous injuries, pre-injury Tegner activity level (≥ 7 or < 7), time from accident to surgery, sport activity (contact vs. non-contact sports) and pre-operative side-to-side knee anteroposterior translation. Backward stepwise exclusion was than performed based on p value. A level of significance of $p = 0.05$ was set. The Kaplan–Meier curve was used to determine the incidence of treatment failure in single and multiple bundle ACL tears. Differences between both groups were tested using the log-rank test. Post hoc power analysis considering the sample sizes below and the difference observed in complication rates at $\alpha = 0.05$ was calculated to be 0.96. Statistical analysis was performed using JMP® (SAS Institute Inc., JMP®, Version 13.0.0, Cary, NC, USA).

Results

Treatment failure

Twenty-two (17.7%) patients suffered from treatment failure during follow-up, which included 14 (11.3%) retears and 8 (6.5%) persisting laxities. Two of the eight patients with laxity and symptomatic subjective instability underwent ACL reconstruction during the follow-up period. Retears occurred 1.4 ± 0.6 years after surgery. All patients with retears underwent ACL reconstruction in a single-step procedure. Table 2 shows the failure rates for each group.

The survival rate increased for one-part ACL tears with intact synovial coverage (log-rank test: $p = 0.0018$) (Fig. 3).

Univariate logistic regression revealed separation of the ACL into parts with tearing of the synovium had a pronounced influence on risk of treatment failure [OR 8.9; 95% confidence interval (CI) 2.0–40.0]. Patient age and body weight also showed a significant influence on risk of failure in the univariate analysis (OR 0.9; 95% CI 0.9–1.0; $p = 0.0016$) and (OR 0.9; 95% CI 0.8–0.9; $p < 0.0001$), respectively. The remaining factors showed no influence as seen in Table 3. After adjustment, ACL separation into parts with synovial disruption maintained the markedly pronounced effect (OR 7.08 CI 1.5–33.3, $p = 0.013$) on failure. Moreover, age demonstrated a small but significant effect (OR 0.86 CI 0.78–0.95, $p = 0.003$).

Table 2 Failure rate among groups

	Overall failure rate	Re-rupture	Insufficiency
1-part tear intact synovium (Group A) ($n=50$)	4.0% ($n=2$)	2.0% ($n=1$)	2.0% ($n=1$)
Synovial disruption ($n=74$)	27.0% ($n=20$)	17.6% ($n=13$)	9.5% ($n=7$)
2-part tear (Group B) ($n=52$)	26.9% ($n=14$)*	23.1% ($n=12$)	3.8% ($n=2$)
>2-part tear (Group C) ($n=22$)	27.3% ($n=6$)¶	4.5% ($n=1$)	22.7% ($n=5$)

*Significantly higher than Group A ($p=0.001$)

¶Significantly higher than Group A ($p=0.003$)

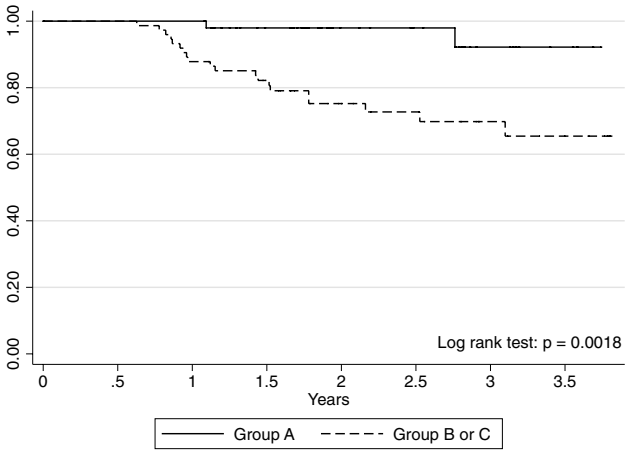

Fig. 3 Kaplan–Meier curve shows the significant difference between one-part ACL rupture with intact synovial coverage (Group A) and groups B and C with involved separation of the ACL into at least two parts with tearing of the synovial membrane

Table 3 Analysis of potential risk factors of treatment failure

	OR (95% CI)	*p* value
Anthropometric data		
Age*	0.86 (0.78–0.94)	< 0.0001
Height	0.98 (0.93–1.04)	n.s
Weight	0.94 (0.90–0.98)	0.0016
Female	2.43 (0.95–6.23)	n.s
ACL injury characteristics		
ACL bundle separation with sheath disruption*	8.89 (1.97–40.02)	0.0004
Concomitant ligamentous injuries		
No vs. yes	0.50 (0.11–2.34)	n.s
Pre-operative a.p. knee instability	1.06 (0.80–1.40)	n.s
Days from accident to surgery	0.99 (0.93–1.04)	n.s
Pre-operative sport activity		
Tegner activity level	1.07 (0.86–1.33)	n.s
Tegner < 7 vs ≥ 7	2.04 (0.73–5.69)	n.s
Non-contact vs. contact sports	1.65 (0.65–4.16)	n.s

*Indicates significance after multivariate adjustment. After adjustment, ACL separation into parts with synovial disruption maintained the markedly pronounced effect (OR 7.08 CI 1.5–33.3, $p = 0.013$) on failure. Moreover, age demonstrated a small but significant effect (OR 0.86 CI 0.78–0.95, $p = 0.003$)

Discussion

The most important finding of this study is reflected in the observation that disruption of the synovial membrane with separation of the underlying ACL bundles is associated with failure of primary ACL repair.

Since the recent renewed interest in primary ACL repair, the indications underwent rapid revision and were obviously narrowed from the initial proposition of treating every fresh ACL tear, to the current recommendation of limiting the indications to proximal ACL tears [1, 3, 16]. As previously mentioned, if primary ACL repair were to regain acceptance and a position in the ACL treatment decision tree, the results must at least be comparable to the gold standard of ACL reconstruction. However, only one comparative study ($n = 60$) by Schliemann et al. [19] compared both techniques in a prospective randomized trial. The study showed that patients with DIS had higher early post-operative activity levels and showed a significantly higher level of post-operative activity, measured with an accelerometric step counter. Functional scores (IKDC and Lysholm Score) and the mean AP translation did not differ significantly between ACL reconstruction and DIS within the first post-operative year [19].

The incidence of treatment failure following DIS was 17.7% in the present study. This incidence is slightly higher compared to other studies analyzing DIS up to 2.5 years post-operatively. Kohl et al. [14] found a retear rate in 6% and persistence of instability in 4% of 50 patients over a 2-year follow-up. Henle et al. [11] reported a retear rate of 2.9% and residual instability in 1.1%. In another study, Henle et al. [10] reported ACL revision in 11% of the 96 followed-up patients at a minimum follow-up of 2 years. Meister et al. [17] reported a retear rate of 15% over 1 year. Osti et al. [18] mentioned an overall failure rate of 17.5%.

It is obvious from the results of the present study that the overall failure rate of 17.7% is rather high compared to ACL reconstruction, for which failure rates between 3% and 7% have been reported in meta-analyses [8]. However, it is fair to underline that many of the studies dealing with ACL repair, including the current study, defined asymptomatic residual clinical laxity as failure [1, 7, 14, 16–18]. The reason for this was failure to achieve the goal of restoring joint stability. The corresponding failure rates are therefore higher than those reported in ACL studies only defining ACL revision as failure. There seems to be a conflation in that regard in academic discussions, and it is of major significance to consider end point definitions of the corresponding studies when referring to failure rates.

The one and rather novel outcome of the study shows that the proximally torn ACL rupture with an intact synovial coverage is associated with a considerably low failure rate and the overall outcome may be at least as good as ACL reconstruction. Removing this torn ACL with intact synovial sheath for the purpose of replacing it with a graft may be an unnecessary and a too aggressive approach.

The reason for improved outcome with ACL tears and intact synovial ACL sheath can only be speculated on, and may be related to the web-like periligamentous capillaries

within the synovial sheath, which are known to provide a major contribution to the ACL blood supply [21]. This might provide an explanation for the inferior failure rates associated with more parts ruptured with disruption of the synovial sheath. Higher energy injuries are likely to disrupt the synovial ACL sheath and alter the organized arrangement of the underlying ACL fascicles.

This study has several limitations. It is a cohort study. To account for potential bias and optimize the accuracy, adjustment of potential confounding variables was performed. Secondly, the sample size and number of failures were rather small to ensure narrow confidence intervals. However, the cohort size was acceptable for the main research question for which sufficient power was achieved. It is also to be emphasized that all patients in the group underwent dynamic stabilization limiting final conclusions to patients undergoing this treatment modality.

Despite these limitations, the presented results do imply that there is without doubt, space for primary ACL repair in the decision tree for a selected group of patients. However, patient selection is crucial. Previous studies pointed toward a higher risk of failure in younger patients performing competitive or pivoting sport activities, as well as in patients with a mid-substance ACL rupture [9, 12, 16, 20, 25]. The current study adds further morphological factors including separation of the ACL fascicles and disruption of the synovial sheath. It is therefore of essence to ensure the integrity of the substance of the proximally torn ACL before deciding on ACL repair.

Conclusion

The results indicate that alongside tear location, further factors related to rupture pattern need consideration when selecting the ideal patient for repair. These include integrity of the ACL bundles and synovial sheath, both needing intraoperative evaluation before the final decision of repair.

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Compliance with ethical standards

Conflict of interest All authors are not compensated for this work.

Ethical approval All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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