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# Traumatic graft rupture after primary and revision anterior cruciate ligament reconstruction: retrospective analysis of incidence and risk factors in 2915 cases

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**Abstract**
*Purpose* To determine incidence and risk factors for traumatic graft rupture following primary and revision anterior cruciate ligament (ACL) reconstruction.
*Methods* All cases of isolated ACL reconstructions (primary or revision) performed at our institution between January 2007 and December 2010 were included. From this group of 2467 primary reconstructions (32.4 ± 12.2 years) and 448 revision reconstructions (33.0 ± 10.4 years), we identified all patients who underwent revision ACL reconstruction following traumatic graft rupture in further course and all patients who underwent contralateral primary ACL reconstruction until January 2014. Age, gender, time from index procedure and graft diameter (for hamstring autografts) were analysed in terms of being a potential risk factor for graft rupture.
*Results* Within a follow-up period of 5.0 ± 1.1 years (3.0–7.0), a total of 82 traumatic graft ruptures were identified, resulting in an incidence of 2.8 %. Seventy-three cases were seen following primary reconstructions (3.0 %), and nine cases following revision reconstructions (2.0 %), respectively (n.s.). Age younger than 25 years was identified as a risk factor for both groups ($p = 0.001$ and $p = 0.008$; odds ratio 6.0 and 6.4, respectively). In primary reconstruction, male patients had a higher risk of graft rupture compared with females (3.7 vs. 1.6 %; $p = 0.005$), and the first year after index procedure was associated with a higher risk of graft rupture compared with the following ($p < 0.001$). Graft diameter did not influence the risk of graft rupture. Incidence of contralateral ACL rupture was 3.1 %, which was not different to the incidence of graft rupture ipsilaterally (n.s.).
*Conclusion* No statistically significant differences were seen between graft rupture incidence of primary and revision ACL reconstructions. Young age (<25 years) and short time to the index procedure (especially within the first year) were confirmed as risk factors for graft rupture in both groups. Male gender was a risk factor for primary reconstructions. Graft diameter had no influence on graft rupture rates. No difference in incidence of graft rupture compared to ACL rupture on the contralateral side was apparent.
*Level of evidence* Retrospective case series, Level IV.

**Keywords** Anterior cruciate ligament · Graft rupture · Graft diameter · Graft failure · Re-rupture · Revision

## Introduction

One of the major complications after anterior cruciate ligament (ACL) reconstruction is graft rupture with a reported average annualized incidence of 0.3–1.5 % per year [3, 7, 8, 11, 13, 21–23, 25, 28, 32]. Recurrent instability leads to revision ACL reconstruction in the majority of these most commonly young and active patients, which is surgically demanding and associated with significant morbidity. Generally, results of primary ACL reconstruction seem to be superior to those of revision ACL reconstructions [29]. Finally, from an economic perspective, subsequent and sometimes multi-staged revision procedures lead to considerable costs.

Young age, high activity level, non-anatomical tunnel position and time from surgery have been reported as risk

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factors for ACL graft rupture [2, 3, 13, 28]. Factors like gender, graft choice and graft diameter are still controversially discussed [2, 6, 13, 15, 18]. To our knowledge, no study has systematically analysed graft rupture in revision ACL reconstruction so far.

The purpose of this retrospective study was to determine the incidence of graft rupture after primary and revision ACL reconstruction. Further, risk factors for graft rupture for both groups were identified, and differences between primary and revision ACL reconstructions were analysed. Incidence of contralateral ACL injury was determined and compared to the incidence of graft rupture.

## Materials and methods

All cases of isolated ACL reconstructions (either primary or revision reconstruction) at our institution from January 2007 until December 2010 were included. Demographic data and surgical details (graft choice, diameter and type of fixation) were obtained from hospital charts and operational reports.

In total, 2915 cases of ACL reconstruction were identified, with 2467 primary reconstructions and 448 revision reconstructions, respectively. Table 1 shows demographic data and surgical details of both groups. From this group, we identified all patients who underwent further revision ACL reconstruction at our institution following traumatic graft rupture from the time of index operation until January 2014. For analysis of the incidence of contralateral ACL rupture 117 patients of this group with insufficient or reconstructed ACL contralaterally at time of index procedure were excluded. From the remaining 2.798 patients we identified all who underwent contralateral ACL reconstruction within the same period.

Again, hospital charts and operational reports of these cases were screened for demographic data, time from index procedure to graft rupture, activity at time of graft rupture and surgical details of revision reconstruction, and relevant data were extracted. Figure 1 shows the activity of patients at time of graft rupture for cases of preceding primary and revision ACL reconstruction.

The incidences of traumatic graft rupture following primary reconstruction or revision reconstruction and the incidence of contralateral ACL injury were calculated and compared. Age, gender and time from index procedure were analysed in terms of being a potential risk factor for graft rupture. The graft diameter of hamstring grafts was analysed for both primary and revision reconstructions. In prior studies, a graft diameter of 8 mm was reported to be a critical limit. Therefore, our data were analysed whether these findings could be confirmed or rejected [6, 15].

### Surgical technique

All operations were performed by specially trained orthopaedic surgeons arthroscopically in standardized technique,

**Table 1** Age at time of index procedure, gender distribution, graft choice and fixation

| | Primary reconstructions ($n = 2467$) | Revision reconstructions ($n = 448$) | $p$ value |
|---|---|---|---|
| Age (years) | 32.4 ± 12.2 | 33.0 ± 10.4 | n.s. |
| Sex | | | |
| Male | 1.551 (62.9 %) | 323 (72.1 %) | <0.001 |
| Female | 916 (37.1 %) | 125 (27.9 %) | |
| Graft | | | |
| Hamstrings | 2.448 (99 %) | 372 (83 %) | <0.001 |
| Quadriceps | 19 (1 %) | 76 (17 %) | |
| Fixation | | | |
| Interference screws | 2.385 (97 %) | 448 (100 %) | <0.001 |
| Button | 82 (3 %) | | |

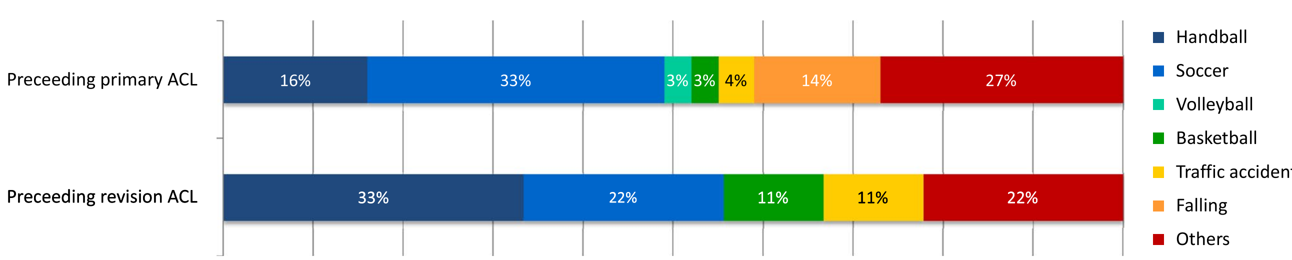


**Fig. 1** Activity at time of traumatic graft rupture

**Table 2** Incidences of graft rupture after an average 5-year follow-up

| | Reconstructions | Graft ruptures | Cumulative incidence of graft rupture (%) |
|---|---|---|---|
| Overall ACL | 2915 | 82 | 2.8 |
| Primary ACL | 2467 | 73 | 3.0 |
| Revision ACL | 448 | 9 | 2.0 |

*ACL* anterior cruciate ligament

using autologous tendons, antero-medial portal drilling for femoral tunnel placement and aperture fixation with interference screws (except for patients with open growth plates).

In primary reconstructions, a four-strand semitendinosus–gracilis tendon autograft was used. In some cases where both ipsi- and contralateral hamstring tendons were used before, an ipsilateral quadriceps tendon autograft was used. In revision cases, either contralateral semitendinosus/gracilis tendons or quadriceps tendon with patellar bone block was used depending on availability and presence of tunnel enlargement.

Aperture fixation was done using biodegradable interference screws on both the femoral and tibial side for hamstring grafts (BioRCI-HA, Smith and Nephew, Andover, MA, USA; MegaFix-CP, Karl Storz, Tuttlingen, Germany). Quadriceps tendons were fixed with titanium interference screws on bone block side (femoral; MegaFix-T, Karl Storz, Tuttlingen, Germany; cannulated interference screw, ConMed Linvatec, Largo, FL, USA). In revision reconstructions, a tibial hybrid fixation with additional non-absorbable suture material fixed to a small fragment screw was used. In all cases of open growth plates, hamstring tendons were used. Fixation was done with button (EndoButton, Smith and Nephew, Andover, MA, USA) on the femoral side and a hybrid fixation with reversed biodegradable screw (RetroScrew, Arthrex, Karlsfeld, Germany) and button (EndoTack, Karl Storz, Tuttlingen, Germany) on the tibial side. Table 1 provides an overview of used grafts and fixation technique.

The study protocol of this retrospective investigation was approved by the Ethics Committee of the Landesärztekammer Baden-Württemberg (reference number F-2014-111).

### Statistical analysis

Statistical analysis was performed using JMP (Version 9.0.0, SAS Institute Inc., Cary, NC, USA). For statistical evaluation of nonparametric data in unrelated samples, the Mann–Whitney $U$ test was used. Categorical variables were analysed using Chi-square and Fisher's exact test. All reported $p$ values are two-tailed, with an alpha level <0.05 considered as significant. Unless otherwise stated, descriptive data are demonstrated as mean ± standard deviation (and range).

## Results

Within a follow-up period of 5.0 ± 1.1 years (3.0–7.0) for both groups (primary and revision ACL reconstructions), a total of 82 traumatic graft ruptures (2.8 %) were identified (Table 2). Seventy-three ruptures were seen in the group of primary ACL reconstructions resulting in an incidence of 3.0 % and nine ruptures in the group of revision ACL reconstruction with an incidence of 2.0 %. The difference was not statistically significant (n.s.).

The average age at time of graft rupture was 24.9 ± 8.8 years in the group of primary reconstruction and 26.5 ± 9.1 years in revision reconstruction. Figure 2 shows the incidence of graft rupture depending on age at time of reconstruction. Patients younger than 25 years at time of index procedure had a significant higher incidence of graft rupture compared with patients 25 years or older in primary (6.6 vs. 1.2 %; $p = 0.001$; odds ratio 6.0) and revision (5.4 vs. 0.9 %; $p = 0.008$; odds ratio 6.4) reconstruction.

A higher incidence of graft rupture was seen in male patients compared with females after primary reconstruction, with 3.7 and 1.6 %, respectively ($p = 0.005$). Incidence of graft rupture in revision reconstruction was 2.5 %

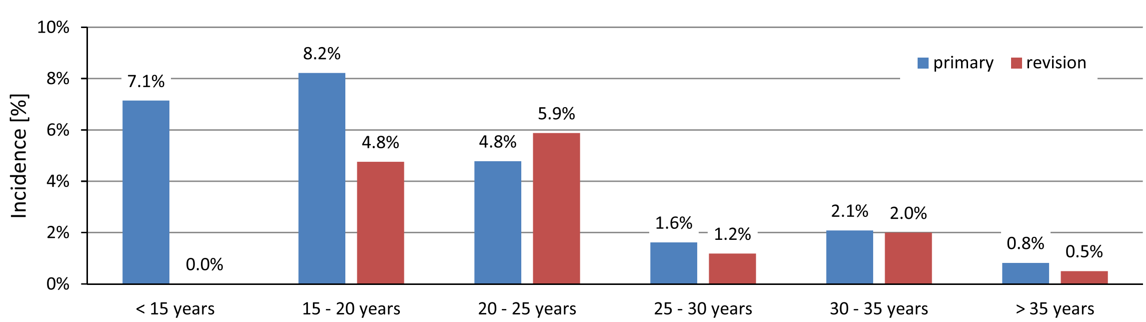


**Fig. 2** Incidence of graft rupture depending on age at time of index procedure for primary (*blue*) and revision (*red*) reconstructions

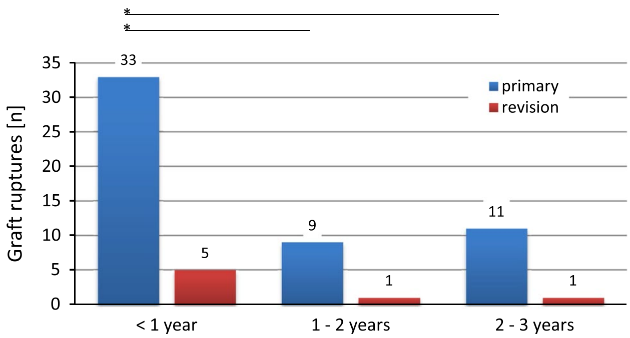


**Fig. 3** Distribution of cases of graft rupture within the first 3 years from the index procedure for primary (*blue*) and revision (*red*) reconstructions. *$p < 0.001$

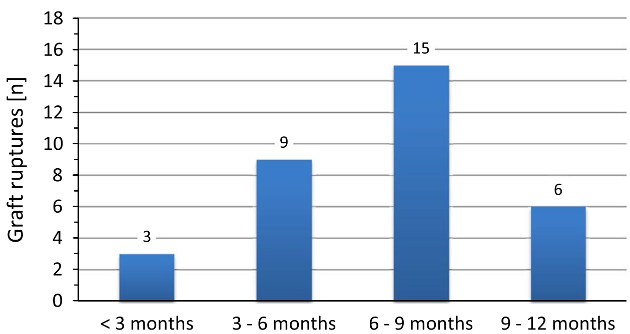


**Fig. 4** Distribution of cases of graft rupture within the first year in intervals of 3 months after primary reconstructions

**Table 3** Diameter of hamstring tendon grafts with and without graft rupture after primary and revision reconstruction

| | Graft rupture (*n*) | Graft diameter (mm) | *p* value |
|---|---|---|---|
| Primary reconstructions ($n = 2448$) | No (2375) | 7.9 ± 0.6 | n.s. |
| | Yes (73) | 7.8 ± 0.6 | |
| Revision reconstructions ($n = 372$) | No (366) | 8.2 ± 0.8 | n.s. |
| | Yes (6) | 8.2 ± 0.9 | |

for males and 0.8 % for females (n.s.). The incidence of graft rupture within the first year after the index procedure was 1.3 % for primary and 1.1 % for revision reconstructions, respectively. After primary ACL reconstruction, a significant higher number of graft ruptures were seen within the first year compared with the second ($p < 0.001$) and the third ($p < 0.001$) years (Fig. 3). Further, within the first year most graft ruptures occurred between 6 and 9 months (Fig. 4). In the group of revision reconstruction, a comparable pattern was seen, although statistical evaluation is not reasonable possible due to the limited number of cases (Fig. 3).

Twelve graft ruptures after primary reconstruction occurred early within 6 months to the index operation: in six cases (50 %), patients fully returned to pivoting sports very early on the basis of their own decision, in four cases (33 %) patients were involved in accidents and in two cases (17 %) graft rupture occurred while performing sport-specific strains within late stages of rehabilitation.

Graft diameter did not influence the risk of graft rupture (Table 3), and no statistically significant difference was seen comparing grafts larger than 8 mm to 8 mm or less (n.s.).

Incidence of ACL rupture on the contralateral side was 3.1 % (86 of 2.798 cases), and was not significantly different to graft rupture ipsilaterally (n.s.).

## Discussion

The most important findings of the present study were incidence rates for traumatic graft rupture of 3.0 % in primary and 2.0 % in revision ACL reconstructions, respectively, with no statistically significant difference in incidence rates between these groups. The study was based on nearly 3.000 ACL reconstructions (including more than 400 revisions) and an average follow-up of 5 years. To our knowledge, this is the first study investigating in graft rupture rates of revision ACL reconstructions. Young age (<25 years), short interval of time to the index procedure (especially the first year) and male gender (in primary reconstructions) were confirmed as risk factors for graft rupture, whereas graft diameter had no influence. No difference was seen between the incidence of graft rupture or contralateral ACL injury.

We found an incidence of 3.0 % graft ruptures within a 5-year follow-up after primary reconstruction (average annualized incidence of 0.6 %). In the literature an average annualized incidence of 0.3–1.5 % per year has been previously reported [3, 7, 8, 11, 13, 21–23, 25, 28, 32]. However, there is a considerable heterogeneity in study design, used grafts, surgical technique and follow-up period. Webster et al. [28] reported on an incidence of 4.5 % for graft rupture after primary ACL reconstruction in 750 cases after an average follow-up period of 4.8 years (minimum 3 years). Hamstring tendons were used as graft in the majority of their cases. The reported incidence is comparable to our findings, but by the use of postal questionnaires and with a follow-up rate of 75 %, some re-injuries and graft ruptures might have been missed, and the actual incidence of graft rupture might actually be higher than they detected. Wright et al. reported on a pooled graft rupture rate after primary ACL reconstruction of 5.8 % (range 1.8–10.4 %) in a systematic review of six prospective studies (level I or II, all grafts were autografts) with a minimum follow-up of 5 years [8, 11, 21, 22, 24, 33]. In contrast to our study, a bone–tendon–bone graft was used in the majority of the included cases. Further, in some of the included studies, trans-tibial techniques for femoral tunnel placement were used. The fact that non-ideal tunnel positioning is associated with higher failure rates (odds ratio 5.0) must be considered [13]. From the Swedish National Anterior Cruciate Ligament Register, Kvist et al. [12] reported on a revision rate of 3.3 % for patients who had a minimum follow-up of 5 years after primary ACL reconstruction.

In revision ACL reconstruction, an incidence of 2.0 % after 5 years was seen (average annualized incidence of 0.4 %). To our knowledge, no study has so far systematically investigated in the incidence of graft rupture in revision ACL reconstruction. We have seen a tendency towards a lower graft rupture rate in this group compared with primary reconstruction, but the reason for this is unclear. Although we did not obtain activity level data and cannot present data on percentage of patients returning to high-impact sporting activities, it is assumable that some patients reduce this after suffering graft rupture and subsequent revision reconstruction, which might explain this issue. Due to the limited number of cases, a comparison of graft choice (quadriceps vs. hamstring tendons) in revision reconstructions is not reasonable possible.

With regard to activity level at time of graft rupture, the majority of graft ruptures for both primary and revision reconstructions actually occurred in performing high-impact contact and pivot sporting activities. Webster et al. [28] reported on an odds ratio of 3.9 for graft rupture when returning to cutting/pivoting sports.

A peak graft rupture incidence was seen in patients between 15 and 20 years after primary reconstructions and between 20 and 25 years after revision reconstructions. With a cut-off at 25 years, a considerable odds ratio of approximately 6 was seen in both groups for patients younger than this. Young age has been reported to be an independent risk factor for graft rupture by several authors [3, 10, 12, 14, 25, 28]. It has not been determined whether age per se is a risk factor or whether age represents a proxy for other factors (e.g. returning to high-impact sporting activities) [4, 25, 28].

In our study, male patients were more than twice likely to suffer graft rupture after primary ACL reconstruction compared with females. In revision cases, a similar tendency was seen, although absolute numbers might not be sufficient to reveal a statistically significant difference. Female gender is known to be associated with a higher risk of ACL rupture [1, 16]. Although several studies reported on a higher incidence of graft rupture in male patients, Paterno et al. contrarily found a four times higher incidence for a second ipsilateral ACL injury in female athletes compared with males [3, 13, 18, 25].

The highest incidence was seen within the first year after surgery in primary reconstructions, especially between 6 and 9 months. A considerable number of graft ruptures also occurred within the first 6 months, which were in most cases due to very early sport-specific strains or complete re-entry in pivoting sports on patient's own decisions. It might be assumed that the characteristic timing of graft rupture within the first year after reconstruction is caused by re-entry in unrestricted sporting activity, participation in competition and therefore increasing the risk of injury. In addition some patients may still have a certain lack of muscular and coordinative ability [20]. Similar to our data other authors reported on an increased risk of ACL graft rupture within the first 12 months after reconstruction [17, 19, 23]. Although subsequent years show lower numbers of graft ruptures, long-term follow-up studies reported on an approximately linear increase in overall graft rupture rates up to 12 % after 15 years [3, 13, 24]. A comparable temporal distribution of graft ruptures was seen after revision ACL reconstruction, but due to the limited number of cases, a reliable statistical analysis is not possible.

No correlation was seen between graft diameter and failure rate in our study, neither in primary nor in revision ACL reconstructions. The influence of graft diameter on the incidence of graft rupture is controversially discussed. In contrast to our results, a recently published review including four clinical studies investigating failure rate after ACL reconstruction using quadruple hamstring autograft reported on a decreased failure rate when graft diameter was equal to or larger than 8 mm [6]. A total of 913 cases were included in this review. The initial maximum load to failure of hamstring tendon grafts is equal to or up to a 100 % higher than the maximum load to failure of the native ACL. This has been confirmed in several studies where four-strand grafts as well as smaller two-strand grafts were investigated [9, 30, 31]. When hamstring tendon autografts are used, graft diameter is predefined within certain limits depending on anatomical conditions. Anthropometric studies have shown to be accurate in predicting hamstring graft diameter, with height as the most common predictor of larger grafts [5, 26, 27]. It might be assumed that larger individuals need larger grafts and that not absolute diameter predicts failure rate, but that depending on anthropometric factors like height and weight of a person and resulting strains on the ACL, an individual critical graft diameter exists. Further studies are necessary to figure out relevant factors and to define the resulting critical size.

There were no differences in the incidence of graft rupture compared to contralateral ACL rupture. This is in line with other studies that reported on similar or even higher rates of ACL rupture contralaterally [3, 28]. Leys et al. reported on a higher incidence of contralateral ACL injury when a bone-patellar-tendon-bone graft was used compared to hamstring tendons [13].

Graft rupture is one of the major complications in ACL surgery. Our study presents reliable data on the incidence of primary and for the first time also of revision

ACL reconstruction as well as associated risk factors. Thus, cases with a high risk of graft rupture might be better identified and re-injury might be prevented. Certainly, some limitations of our study have to be considered. The major limitation is the retrospective setting, identifying only patients treated for graft rupture at our institution. An unknown number of patients with recurrent instability might have not been treated or might have been treated elsewhere with revision surgery. Therefore, the actual incidence of graft rupture might be higher. Further, the activity level after primary and revision reconstruction was not obtained but might play a key role in the occurrence of graft rupture. As there might be a further decrease in activity level following the second stabilization, comparison of graft rupture rates between primary and revision cases must be done with caution.

## Conclusion

No statistically significant differences were seen between graft rupture incidence of primary and revision ACL reconstructions. Young age (<25 years) and short time to the index procedure (especially within the first year) were confirmed as risk factors for graft rupture in both groups. Male gender was a risk factor for primary reconstructions. Graft diameter had no influence on graft rupture rates. No difference in incidence of graft rupture compared to ACL rupture on the contralateral side was apparent.

**Compliance with ethical standards**

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

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