Analysis of different causes and risk factors of anterior cruciate ligament reconstruction failure

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Background
Anterior cruciate ligament (ACL) reconstruction failure is characterized by recurrent knee instability, stiffness, or pain that prevents a patient from participating in his or her chosen activities. The etiology of ACL reconstruction failure is multifactorial; surgical errors, infection, trauma, and/or associated pathology are blamed.

Aim
The purpose of this retrospective study was to define and analyze the causes of failure of ACL reconstruction.

Patients and methods
This study reviewed 300 patients who underwent ACL reconstructions, which were performed at Mansoura knee Surgery and Arthroscopy Unit over a 5-year period from 2005 to 2010. Untreated laxity, angular deformity, femoral and tibial tunnel malposition, method of fixation, and meniscus surgery were assessed; new trauma and infection were recorded. Assessment included knee stability tests, range of motion, and International Knee Documenting Committee scoring system evaluation.

Results
In our study, the rate of ACL reconstruction failure was 7%. The main causes of failure were malpositioned tunnels (66.5%) and new trauma (24%). However, 15% of malpositioned tunnels caused failure and 50% of trauma caused failure. Moreover, 33% of infection, 5% of extracortical fixation, 2.2% of partial menisectomy, and 6% of preoperative varus knee were associated with failure.

Conclusion
Malpositioned tunnels and new trauma are the dominant causes of ACL reconstruction failure. Infection, extracortical fixation, partial menisectomy, and varus knee are risk factors for ACL reconstruction failure; thus, the failure is multifactorial.

Keywords:
ACL failure, risk factors

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Introduction

Owing to current techniques, modern equipments, better graft fixation methods, accelerated rehabilitation programs, and increased knowledge of anterior cruciate ligament (ACL) anatomy and biomechanics, ACL reconstruction has been a successful operation achieving good results in 75–95% of patients [1]. ACL reconstruction failure is characterized by recurrent knee instability, stiffness, or pain that prevents a patient from participating in his or her chosen activities [2].

Although risk factors for failure or poor outcomes of reconstruction have been determined and graft failure has been estimated to occur in 10–15% of patients [3], the true incidence of failed ACL reconstruction is difficult to calculate and is likely underreported [4].

The etiology of ACL reconstruction failure is multifactorial [5]; surgical errors, trauma, infection, and/or associated pathology are accused [1]. Surgical errors include tunnel malposition, inadequate graft tensioning or fixation, and graft impingement [1,3,6]. Malpositioned tunnels are responsible for 60–80% of all graft failures after ACL reconstruction [3,6,7].

At Mansoura Knee Surgery and Arthroscopy Unit, we reviewed our work in ACL reconstruction over a 5-year period (2005–2010). We encountered 21 patients with failed reconstruction out of 300 patients. The aim of this retrospective study was to define and analyze the possible causes for failure of ACL reconstruction.

Patients and methods

This study reviewed 300 patients with ACL reconstructions that were performed at Mansoura

Knee Surgery and Arthroscopy Unit over a 5-year period from 2005 to 2010. Untreated laxity, angular deformity, femoral and tibial tunnel malposition, method of fixation, and meniscus surgery were assessed; new trauma and infection were recorded. Assessment included knee stability tests, range of motion, and International Knee Documenting Committee scoring system evaluation.

The position of the tibial tunnel aperture was measured on the anteroposterior radiographs, from the most medial point of the tibial plateau to the most lateral point of the tibial plateau, and was normalized to the percentage of medial–lateral distance on the tibial plateau [8]. On the lateral radiographs, the position of the tibial aperture was measured with respect to the tibial plateau along the Amis and Jakob [9] line (tibia percentage, which is the percentage of the distance from anterior margin on the tibia to the center of the tunnel along the Amis and Jakob line).

The position of the femoral tunnel aperture was measured according to the quadrant method described by Bernard *et al.* [10]; the femoral length was measured as the distance from the most posterior contour of the lateral femoral condyle parallel to the Blumensaat line, and femoral height was measured from the most inferior contour of the lateral femoral condyle perpendicular to the Blumensaat line. The center of the femoral tunnel was measured and normalized to the posterior–anterior percentage of the length and proximal–distal percentage of the height of the lateral femoral condyle. The coronal and the sagittal drill angles were measured on anteroposterior and lateral radiographs, respectively, between the joint line and the long axis of the tunnel [11].

Results

Of 300 patients, 21 cases had ACL reconstruction failure – that is, our rate of ACL reconstruction failure was 7%. The main causes of ACL reconstruction failure was malpositioned tunnels (66.5%), new trauma (24%), and infection (9.5%). Other causes predisposed to and associated with but not the main causes of failure were superficial infection (19%), extracortical fixation (19%), partial menisectomy (19%), and varus knee (4.8%). Of the 300 patients, 93 patients had malpositioned tunnels, 10 patients were exposed to new trauma, six patients were exposed to infection, 80 patients underwent extracortical fixation, 180 patients underwent partial menisectomy at the time of ACL reconstruction, and 16 patients had uncorrected preoperative varus knee.

Table 1 shows that, of the 93 patients who had malpositioned tunnels, 14 patients developed ACL reconstruction failure, 10 patients had anterior both tibial and femoral tunnels, and four patients had anterior and superior femoral tunnels. Malpositioned tunnels occurred in 31% of our ACL reconstructions and represented 66.5% of causes of ACL reconstruction failure.

Of the 10 patients exposed to new trauma, five of them attained ACL reconstruction failure. Twisting with weight-bearing was the causative trauma that led to graft failure in five patients and meniscal injury in four patients who were managed through knee arthroscopy. Motor car accident was the causative trauma in the 10th patient and led to fracture through the femoral tunnel with no displacement; it was managed conservatively and healed, and the patient had lower International Knee Documenting Committee scoring. Trauma occurred in 3.3% of our ACL reconstructions and represented 24% of causes of ACL reconstruction failure.

Of the six patients exposed to infection, two of them developed ACL reconstruction failure. All infected cases were managed with arthroscopic wash and antibiotics; four cases were controlled and two cases developed recurrent infection and failure with the removal of graft tissue. The infection occurred in 2% of our ACL reconstructions and represented 9.5% of causes of ACL reconstruction failure.

Of the 80 patients who underwent extracortical fixation, four of them had ACL reconstruction failure but the extracortical fixation was not the main cause of failure. The extracortical fixation was present in 26.5% of our ACL reconstructions and represented 19% of the risk factors for ACL

Table 1 Patient findings (causes and risk factors for anterior cruciate ligament reconstruction failure)

	Tunnel malposition	Extracortical fixation	Partial menisectomy	Angular deformity	New trauma	Infection
N	93	80	180	16	10	6
Caused the failure	14	–	–	–	5	2
Associated the failure	2	4	4	1	–	–
Risk factor for late failure	77	76	176	15	5	4

reconstruction failure. Of the 180 patients who underwent partial menisectomy at the time of ACL reconstruction, four of them had ACL reconstruction failure but partial menisectomy was not the main cause of failure. Partial menisectomy was performed in 60% of our ACL reconstructions and represented 19% of the risk factors of ACL reconstruction failure. Of the 16 patients with uncorrected preoperative varus knee, one of them had ACL reconstruction failure but the varus knee was not the main cause of failure. Varus knee was observed in 5.3% of our ACL reconstructions and represented 4.8% of ACL reconstruction failure.

We presented two cases with ACL reconstruction failure to analyze the causes and risk factors of failure (Table 2 and Figs 1 and 2).

Case 1: the main cause of failure was anterior femoral and tibial tunnels

There was no history of infection or new trauma. On examination, there was a varus deformity of 17° (Fig. 1c). The aperture of the tibial tunnel was too anterior and a little bit medial (22.8% from the anterior border and 43.3% from the medial border of the tibia) (Fig. 1a). The aperture length was 1.5 (the tibial tunnel diameter), the sagittal drill angle was 75°, and the coronal drill angle was 45° (i.e. tibial tunnel inclination was vertical and medial (Fig. 1b). The aperture of the femoral tunnel was too anterior and a little bit superior (53.5% from the posterior border of the lateral femoral condyle and 30% from the inferior border of the lateral femoral condyle). The graft fixation was extracortical using the endobutton on the femoral side and cortical screw and plastic washer on the tibial side (Fig. 1c). On examination, the anterior drawer test, the Lachman test, and the pivot shift test were positive (i.e. the instability was both anteroposterior and rotational).

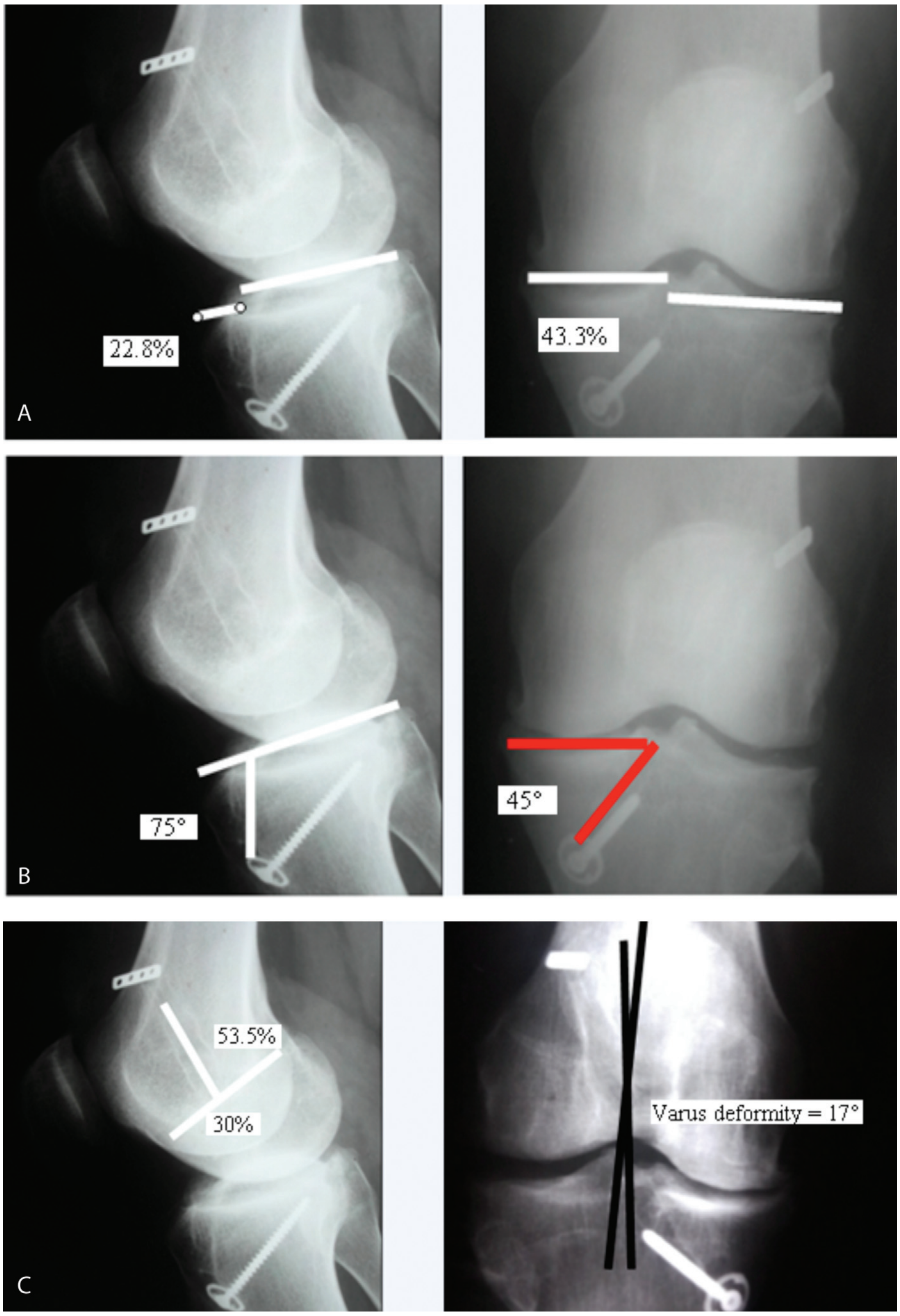
Case 2: the main cause of failure was new trauma

There was no history of infection. After 3 years of ACL reconstruction with stable knee, there was a history of new trauma in the form of twisting and weight-bearing, leading to recurrent instability and ACL reconstruction failure. There was no angular deformity or coronal instability. The aperture of the tibial tunnel was too anterior and a little bit medial (33% from the anterior border and 41.8% from the medial border of the tibia) (Fig. 2a). The aperture length was 1.5 (the tibial tunnel diameter), the sagittal drill angle was 65°, and the coronal drill angle was 70° (i.e. tibial tunnel inclination was slightly horizontal and central (Fig. 2b). The aperture of the femoral

Table 2 Patient findings (case 1 and case 2)

	Infection	New trauma	Angular deformity	Coronal instability	Aperture position of tibial tunnel from the anterior border of the tibia (%)	Aperture position of tibial tunnel from the medial border of the tibia (%)	Aperture length of tibial tunnel relative to tunnel diameter	Sagittal drill angle (deg.)	Coronal drill angle	Aperture position of femoral tunnel from the posterior border of the lateral femoral condyle (%)	Aperture position of femoral tunnel from the inferior border of the lateral femoral condyle (%)	Extracortical graft fixation
Standard	–	–	–	–	43–46	44–48	1	Not fixed	60–70	24.8	28.5	–
Case 1	–	–	+	–	22.8	43.3	1.5	75	45	53.5	30	+
Case 2	–	+	–	–	33	41.8	1.5	65	70	16	20	+

Figure 1



(a) The tibial tunnel aperture was too anterior and little bit medial. (b) Tibial tunnel inclination was vertical & medial. (c) The femoral tunnel aperture was too anterior and little bit superior. The graft fixation was extracortical on the femoral side and the tibial side.

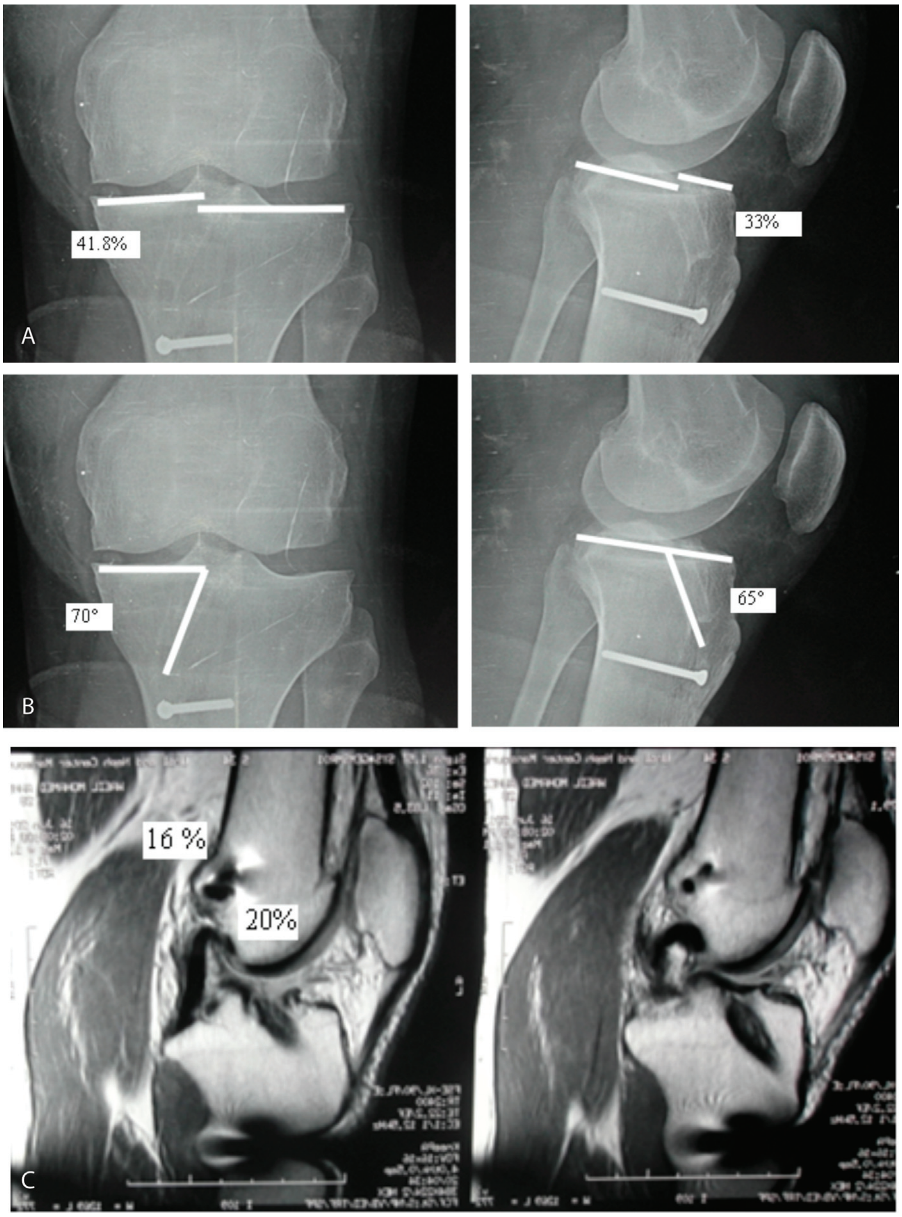
tunnel was too posterior and inferior (16% from the posterior border of the lateral femoral condyle and 20% from the inferior border of the lateral femoral condyle) (Fig. 2c). The graft fixation was extracortical on the tibial side using cortical screw and plastic washer. On examination, the anterior drawer test, the Lachman test, and the pivot shift test were positive – that is, the instability was both anteroposterior and rotational.

There is an overlap of causes and risk factors of failure (Figs 1 and 2). A single causative factor was not the only but the main cause of failure. A single risk factor was not a cause but led to other causes of failure (Figs 1c and 2a–c).

Discussion

Traumatic ACL reconstruction failure can be divided into early and late failures. Early failures are uncommon and late failures occur in 5–10% of patients [12]. However, Diamantopoulos *et al.* [6] recently showed that repeat traumatic injury was the reason for ACL revision in 25% of patients.

Figure 2



(a) The aperture of tibial tunnel was too anterior and little bit medial. (b) Tibial tunnel inclination was slightly horizontal & central. The graft fixation was extracortical on the tibial side. (c) The aperture of femoral tunnel was too posterior and inferior. Traumatic graft rupture.

Early failures occurring before biological incorporation of the graft, at the site of graft fixation, are attributed to trauma, aggressive rehabilitation, or premature return to running or cutting activities before regaining neuromuscular control. Late failures occur after incorporation and remodeling of the graft, involving injury to the intra-articular portion of the graft, and can be associated with technical errors, tunnel malposition, or biological failure [12].

Anatomic ACL reconstruction was believed to be the key point for the success of the operation [8]. Accurate tunnel placement is essential in the reconstruction of the ACL, without which the function of the reconstructed knee cannot be restored [13]. Nonanatomic tunnel placement may result in abnormal knee kinematics, graft stretching, or impingement [8].

The recommended position of the tibial tunnel aperture is 43–46% from the anterior border [9,14] and 44–48% from the medial border upon the tibial plateau [14,15]. If the tibial tunnel aperture is too anterior it causes notch impingement and loss of knee extension [16]. If the aperture is too posterior it causes posterior cruciate ligament impingement, loss of knee flexion [14], and vertical graft orientation [17]. If the aperture is too lateral it causes impingement with the lateral femoral condyle [18], synovitis, and effusion [19]. If the aperture is too medial it causes graft impingement with the medial femoral condyle. Graft impingement leads to graft failure due to attrition of the graft substance and finally tear of the reconstructed ACL [20]. A vertical graft leads to rotational instability, negative Lachman test, and positive pivot-shift test [17,18].

A wide range of tibial drill-guide angles and transverse angles have been used for ACL reconstruction in previous studies [21]. The recommended drill angles were 60–70° in the coronal plane [11,22]. Because of the individual variation in the Blumensaat line angle, the tunnel angle in the sagittal plane cannot be recommended as a fixed value, but the tunnel should be placed posterior enough not to cause roof impingement [23]. An increase in drill guide angle creates higher stress on the graft in the central part, at the tunnel aperture, and in the meniscal insertions. Thus, it influences graft tension and contributes to tunnel widening [24]. Furthermore, increasing the drill guide angle increases the bone tunnel length, which ultimately affects the graft type and fixation technique [25].

Both the area and the orientation of the tibial tunnel aperture depend on the drill-bit size and the drill angle [26]. Increasing the area of tibial tunnel aperture increases the risk of damaging these surrounding structures [27]. In addition, increasing the aperture size while keeping the graft size constant also increases the ratio between the aperture area and the graft cross-sectional area; this may provide more space for the graft to move at the tunnel aperture [26] and decreases graft healing [28].

The angle of the tibial tunnel with reference to the tibial plateau has a role in the technique for preparing the transtibial femoral tunnel, in that the orientation of the tibial tunnel almost determines the femoral tunnel position [20]. Some studies have determined that transtibial femoral tunnel drilling does not reach the anatomic site of the ACL insertion but rather a high tunnel position [29].

To determine the anatomic site of the ACL insertion, the measurement was performed according to the quadrant method described by Bernard *et al.* [10], who showed that the center of the ACL insertion was located at 24.8% (along the Blumensaat line) and 28.5% (perpendicular the Blumensaat line) of the condyle with respect to the Blumensaat line. Therefore, the more posterior and more distal the tunnels, the more anatomic the tunnel placement and fewer the incidences of tunnel enlargements. Inadequate tunnel placement commonly occurs when the femoral tunnel is placed too anterior and too superior leading to the loss of knee flexion, excessive graft tension, and failure by cyclic loading [1] and vertical graft orientation. Several previous studies [30–32] have shown that the lower graft could better control the rotational stability in single-bundle ACL reconstructions.

Conclusion

Malpositioned tunnels, new trauma, and infection are the dominant causes of ACL reconstruction failure. Superficial infection, extracortical fixation, partial menisectomy, and varus knee are risk factors for ACL reconstruction failure.

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Conflicts of interest

There are no conflicts of interest.

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