Original article

The role of computer assisted navigation in revision surgery for failed anterior cruciate ligament reconstruction of the knee: A continuous series of 52 cases

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A B S T R A C T

Introduction: The causes of failure of anterior cruciate ligament (ACL) reconstruction mainly involve incorrect tunnel positioning. There is no intraoperative tool allowing the surgeon to test graft biomechanics and to confirm that the new graft is in an optimal position.

Hypothesis: Control is improved with computer assisted navigation.

Material and methods: In this retrospective study, revision ACL reconstruction was performed with a new autologous graft in a continuous series of 52 failed ACL reconstructions. A computer assisted navigation system was used intraoperatively in all knees. Evaluation with this system confirmed the position of old and new tunnels as well as intraoperative laxity.

Results: Evaluation of tunnel position based on traditional radiological criteria found in the literature significantly underestimated graft biomechanics: 69% of the cases presented with unfavorable graft anisometry (mean: 13 ± 2.2 mm) while the correct position of the tibial tunnel was identified in 64% of cases on radiography and the femoral tunnel in 48%. All new grafts were optimally positioned by the computer assisted navigation system with a mean isometry of 3.2 (±0.7) mm. Comparative pre- and postoperative evaluation of laxity showed a statistically significant improvement (P<0.001): preoperative and postoperative Lachman test: 10.5 ± 2.2 mm and 3 ± 0.5, respectively; global rotational laxity: 24 ± 5° and 37 ± 7° respectively.

Conclusion: The use of a computer assisted navigation system allows optimal positioning of the graft as well as a predictive assessment of laxity.

Type of study: Level IV, retrospective cohort study.

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1. Introduction

Surgical reconstruction of the anterior cruciate ligament (ACL) has become routine: there are approximately 35,000 ligament reconstructions per year in France. A failure rate of between 11 and 20% has been reported in the literature [1–3] with persistent knee instability and rotational laxity with the presence of a positive “pivot shift test” [4,5]. An analysis of the causes of these failures is essential before performing any surgical procedure. Although it is difficult to evaluate, one of the most frequent causes is incorrect tunnel positioning [6–9]. Indeed, analysis of graft position is based on radiographic or MDCT criteria whose reproducibility and interpretation are a subject of debate [10]. However, correct anatomic and isometric tunnel positioning is essential. How can correct tunnel positioning be confirmed during revision surgery? The position should be anatomical within the native area of the ACL, as isometric as possible and should not impinge the intercondylar notch. [11]. According to Gillquist [12], there are significant interindividual anatomical variations in correct tunnel position. For Jagodzinsky [13], optimal tibial tunnel positioning to avoid intercondylar notch roof impingement ranges from using 36% to 62% of the width of anteroposterior tibial insertion surface. There is no predefined position to ensure optimal tunnel placement for the surgeon with conventional tools; especially since the definition of correct tunnel position also varies in relation to each surgeon’s preference [14]. The quality of tunnel positioning is largely responsible for the
differences in objective clinical results observed in the literature with good and very good results ranging from 75 to 90% [15].

Thus, to improve these results, the accuracy of tunnel positioning needed to be improved: surgical computer assisted navigation systems made it possible to achieve this goal. Since 1993 numerous studies in Grenoble, France, have allowed us to develop and apply the concept of an anatomometric positioning of the ACL based on the use of a computer assisted navigation system to obtain a minimal favorable anisometric profile for the graft that does not impinge upon the femoral intercondylar notch [16,17]. At present the computer is the only tool capable of measuring these parameters. We therefore systematically used the computer assisted navigation system for revision ACL surgery to look for a relationship between failed ACL reconstruction and possible graft malposition.

The goal of this study was to analyze the intraoperative intraarticular anatomical and biomechanical results in a continuous series of 52 primary ACL reconstruction failures and to describe a procedure of revision ACL reconstruction using a computer assisted navigation system. This system made it possible to analyze knee kinetics, laxity before and after revision surgery and to record the position of old and new tunnels as well as the isometrics of old and new grafts.

2. Materials and methods

This is a retrospective study in a continuous series of 52 patients (mean age: 27 years old (20–45), 18 women – 34 men, 34 left knees – 18 right). After failure of primary ACL reconstruction (1 synthetic ligament, 30 semitendinosus gracilis [STG] grafts, 21 bone-patellar tendon-bone [BPTB] grafts) all patients underwent revision ACL reconstruction. Patients under the age of 18 when the first graft was performed were excluded. The mean interval between the first ACL reconstruction and the second was 26 months (6–84 months). A sports injury was the cause of the tear in 60% of the cases.

The clinical exam identified a (+) Lachman test in 12 cases and (+++) in 40 cases, the presence of slight rotational laxity in 28 cases and (+) in 24 cases. The mean preoperative laxity on radiological Telor® (150N) was 10 ± 3 mm (7–15).

The surgical technique involved using STG tendon grafts (simple or double bundle) in case of BPTB or synthetic ligament failure and a BPTB graft in case of STG failure. In case of significant preoperative laxity in particular rotational laxity, double bundle ligament reconstruction (7 cases) or lateral tenodesis (3 cases) were performed (Table 1).

3. Computer assisted navigation technique

The computer assisted navigation system described by Julliard [16] and Plaweski et al. [17] was used with the Surgextics workstation (Praxim Medivision®, La Tronche, France) and software for ACL reconstruction (ACL Logics®, Praxim Medivision®, La Tronche, France) without pre- or intraoperative imaging; only anatomical references were used. Virtual images were adapted to conform to the anatomical reality of the patient’s intercondylar notch [18] using the Bone Morphing® procedure. The centers of the primary reconstruction tunnels were visualized. They were recorded by the operator on the anisometry map drawn by the computer. Thus, virtual anisometry of the primary graft could be controlled. The choice of new tunnels was based on this assessment: either the positioning of the primary tunnels was good and could be preserved or it was incorrect and they were abandoned and new tunnels were drilled following the tunnel position presented on the computer screen which presented minimal anisometry and no impingement with the intercondylar notch.

Each knee was evaluated for laxity by an intraoperative Lachman test before and after graft placement (measurements obtained by the computer assisted navigation system). Each measurement was repeated three times and the highest value was recorded. Rotational laxity was evaluated using the same protocol with the knee in 20° flexion with the highest value recorded for each test.

The recorded values were presented as means and standard deviations. Results were analyzed using the student t-test and P < 0.05 was considered to be significant.

4. Results

4.1. Laxity assessment

Mean preoperative and postoperative anterior laxities were 10.5 ± 2 mm (8–17 mm) and 3 ± 0.7 mm (1–7), respectively (Table 2). The preoperative and postoperative global rotational laxities (difference between maximum internal and external rotational laxities) were 37 ± 7 degrees (28–52) and 24 ± 5 degrees (18–30), respectively.

The influence of laxity on the surgical procedure: associated anterolateral reconstruction was performed in 3 cases with insufficient correction of rotational laxity (estimated values after ACL reconstruction were less than 20% of the correction of values determined before graft placement by the computer assisted navigation system).

4.2. Analysis of tunnel position

The position of the tunnels was assessed on AP and lateral X-rays of the knee in full extension based on criteria defined by Howell et al. [20] and Aglietti [21]. Geometric values for this analysis are set out in Fig. 1 with criteria for tibial tunnel positioning (ATB) and criteria for femoral tunnel positioning (AB/AC) (Fig. 1).

The preoperative position of the femoral tunnel tended to be anterior (mean preoperative AB/AC = 58.4 ± 8.3) with an index < 60% in 52% of the cases and was correct in all postoperative cases (index > 60%: mean AB/AC = 65.9 ± 4.5). The preoperative position of the tibial tunnel was incorrect in 36% of the cases (impingement of the intercondylar notch) (negative preoperative ATB: mean = -0.31 ± 2.69) and was correct postoperatively in all cases without impingement with the intercondylar notch (ATB postoperative: mean = 1.2 ± 0.76) (Figs. 2 and 3).

4.3. Biomechanical analysis

The preoperative anisometry curve was unfavorable in 36 cases (69%), and favorable or neutral in 16 cases (Table 2). In the 36 unfavorable cases, mean anisometry was 13 ± 2.2 mm (7–19). The mean anisometry after revision was favorable in all cases and was 3.2 ± 0.7 mm (1–5) (Figs. 4 and 5). In the 7 cases of double bundle reconstruction, the anteromedial bundle was isometric in all cases and the mean isometry of the posterolateral bundle was favorable (3.5 ± 0.5 mm) (2–7).

<table>
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<th>Table 1</th>
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<tr>
<td>Surgical techniques: primary surgery and revision surgery.</td>
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<td>BPTB</td>
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<td>STG</td>
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<td>Synthetic ligament</td>
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<td>Double bundle</td>
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<td>Associated lateral tenodesis</td>
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BPTB: bone-patellar tendon-bone reconstruction; STG: semitendinosus gracilis graft.
Table 2
Pre- and postoperative values.

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<th>Preoperative</th>
<th>Postoperative</th>
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<tr>
<td>Anterior drawer (mm)</td>
<td>10.5 ± 2 (8–17)</td>
<td>3 ± 0.5 (1–7)</td>
<td></td>
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<tr>
<td>Global rotation (degrees)</td>
<td>37 ± 7 (28–52)</td>
<td>24 ± 5 (18–30)</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Anisometry (mm)</td>
<td>13 ± 2.2 (7–19)</td>
<td>3.2 ± 0.7 (1–5)</td>
<td>P&lt;0.001</td>
</tr>
<tr>
<td>Isometry</td>
<td>Unfavorable 36 cases</td>
<td>Unfavorable 0 cases</td>
<td></td>
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<td></td>
<td>Favorable 16 cases</td>
<td>Favorable 52 cases</td>
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Fig. 1. Definition of geometric measurements [19]: radiography of the knee in full extension. A. Measure of impingement with the notch (ATB). B. Measure of the femoral tunnel position (AB/AC). CTT: distance between the center of the tibial tunnel and the anterior edge of the tibial plateau; W: width of the tibial tunnel; STD: width of the tibial plateau; ATB: distance between the anterior edge of the tibial tunnel and the projection of the Blumensaat line on the tibial plateau.

4.4. Analysis of intercondylar notch impingement

Only the new graft could be analyzed: there was contact with the intercondylar notch in 15% of cases.

5. Discussion

Although the goal of this study was not to determine the source of graft failure, our series revealed that 69% of failures were due to unfavorable graft anisometry, usually with incorrect positioning of the femoral tunnel rather than the tibial tunnel. In a study performed by the MARS group [Multicenter ACL Revision Study [22]] the cause of ACL reconstruction failure was considered to be traumatic in 32%, technical in 24%, biological in 7% and combined in 37%.

Fig. 2. Tibial tunnel position. ATB preoperative: mean = −0.31 ± 2.69 (min [-11]–max +5). ATB postoperative: mean = 1.2 ± 0.76 (min 0–max 3.5). P<0.001.

Fig. 3. Femoral tunnel positioning (Aglietti index). AB/AC*100 preoperative: mean = 58.48 ± 8.34 (41–69). AB/AC*100 postoperative: mean = 65.88 ± 4.52 (55–70). P<0.001.

Fig. 4. Initial graft: BPTB failure: incorrect positioning of both tibial and femoral tunnels. Tibial tunnel is much too anterior: there is a conflict with the notch. ATB = −11; femoral tunnel is too anterior: AB/AC = 40; unfavorable anisometry = 9 mm. Revision graft with STG: tibial tunnel: ATB = 0; femoral tunnel: AB/AC = 60; favorable anisometry = 3 mm.
Fig. 5. Computer assisted navigation maps. A. The initial graft is located in an area of unfavorable anisometry and the tibial tunnel is too anterior. The anisometry is 9 mm with an unfavorable curve. B. Revision graft: the femoral positioning of the second graft is located in favorable area with an anisometry of 3 mm. The tibial tunnel is in a more anterior position without impingement with the notch. The isometry curve is horizontal.

In a multicenter study of 293 cases, Trojani et al. [6] found that 50% of failures were due to technical error with three times more errors of the femoral tunnel (36%) than of the tibial tunnel (11%). A tear from a new injury was identified in 30% of the cases.

More important than the intrinsic value of graft anisometry, computer assisted navigation showed that incorrect tunnel positioning was present along with an unfavorable anisometric curve in 69% of the cases in our series. Analysis of isometric mapping made it possible to identify whether the position of the old tunnels was optimal or not and to make sure that the new tunnels were correctly positioned. Although the computer assisted navigation system has been extensively used to evaluate graft isometry in primary ACL reconstruction (navigation was used in 3 cases in this study and tunnel position was optimal in all three cases) only one study has been published on its use for revision ACL reconstruction [23]. Our study has shown that traditional criteria in the literature to define correct or incorrect tunnel position are insufficient because femoral and tibial tunnels positions were considered to be good in 48% and 69% of the cases, respectively on standard imaging while the anisometry curve was unfavorable in 69% of the cases, thus showing the importance of computer assisted navigation to obtain optimal positioning of the graft in revision ACL surgery. A large percentage of grafts were found to be in so-called suboptimal zones. Toplis et al. [24] found that two thirds of tunnels were incorrectly positioned on the sagittal plane [11]. These difficulties are increased by the degree of interindividual variability in the ACL anatomy, which can lead to impingement with the intercondylar notch despite optimal tunnel positioning [12,13].
tunnel positioning can improve clinical results by ensuring that the ACL graft is placed in the best anatomical position, with the best isometry and without impingement with the intercondylar notch.

Zaffagnini et al. [25] showed the importance of computer assisted navigation for revision ACL surgery to evaluate the causes of failure, correctly position new tunnels and control laxity. Colombo et al. [26] used the same computer assisted navigation system as ours and confirmed the interest of associating intraarticular ACL reconstruction with lateral tenodesis to improve rotational laxity.

Control of isometric curves by a “computerized third eye” resulted in favorable graft isometry. Predictive analysis of postoperative laxity showed that isolated intraarticular ACL reconstruction was insufficient in a certain number of cases, so that we associated lateral tenodesis with this procedure in three patients and a double bundle reconstruction in seven [27].

6. Conclusion

Computer assisted navigation makes it possible to adapt surgical procedure(s) by analyzing failures and controlling laxity as well as to associate, if necessary, peripheral reconstruction and to perform an individualized surgical procedure. Conventional criteria found in the literature to analyze ACL graft position may not be sufficient and may underestimate graft malposition. The isometry of the primary graft was precisely determined by computer assistance and showed unfavorable anisometry in 69% of the cases in our study. Placement of the new graft was thus optimized and was favorable in all cases. Control of rotational laxity was also improved by the intraoperative study of laxity and surgical management was optimized by associating a double bundle procedure or lateral tenodesis with the revision procedure.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References