Does bone impaction technique reduce tunnel enlargement in ACL reconstruction?

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Abstract The aim of this study was to investigate effects of bone impaction technique on tunnel enlargement after ACL reconstruction at a minimum 2 years follow-up. Two groups of patients who had been operated upon with the same arthroscopic technique with the exception of tibial tunnel constitution were compared. Twenty-one patients of group A (drilling to 6 mm followed enlargement to 8–9 mm by using dilators) and 23 patients of group B (directly drilling to the size of the graft) were evaluated clinically and radiographically based on multislice computerised tomography (MSCT) retrospectively. At follow-up, there was no statistical difference between tunnel diameters between two groups at the femoral site, but significant difference at the tibial site ($p=0.00192$ for coronal; $p=0.0171$ for sagittal diameter). Both groups were comparable according pre- and postoperative Lysholm and IKDC scores ($p<0.5$ Mann-Whitney U test). Compacted tunnel walls may resist enlargement, suggesting this technique resulted in better tunnel diameter values especially with intratunnel fixation.

Résumé Le but de cette étude est d'analyser à 2 ans de recul les effets de la greffe osseuse impactée sur l'élargissement du tunnel, lors de la réfection du LCA. Deux groupes de patients ont été opérés par la même technique arthro-

scopique, nous avons comparé ces deux groupes. 21 patients du groupe A et 23 patients du groupe B ont été évalués cliniquement, radiographiquement et au scanner, cette analyse a été faite rétrospectivement. Dans le groupe A le tunnel a été foré avec une largeur de 8.57 mm et le groupe B de 8.73 mm (8–9 mm). Au suivi, il n'y a pas de différence de taille de tunnel entre ces deux groupes au niveau fémoral, par contre, il existe une différence significative au niveau tibial ($p=0.00192$ pour le diamètre coronal et $p=0.0171$ pour le diamètre sagittal), ces deux groupes sont comparables, cliniquement en ce qui concerne les scores pré et post opératoire de Lysholm et de l'IKDC ($p<0.5$ Mann-Whitney U test). La technique du tunnel avec os compacté permet de résister à la tendance à l'élargissement de celui-ci.

Introduction

Anterior cruciate ligament (ACL) reconstruction is a successful surgical technique in anterior knee instability associated with rupture of ACL [4, 24]. Many different techniques have been described for ACL reconstruction, with intra-articular placement of the graft the most popular one. However, enlargement and changes in shape at tunnels have been reported, contributing to the complexity of the revision procedures [5, 17, 20, 23]. The aetiology of the enlargement is controversial, and the factors responsible for the enlargement of the tunnel size may be secondary to bone necrosis after high-speed drills with extraction reaming [5].

Compaction drilling is another technique to constitute bone tunnels, which also has advantages in increasing insertion torque and pullout strength of interference screws [1–3]. We hypothesised that a compaction of the tunnel by

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using dilators could create an increased bone mass along the inner surface of the tunnel, and may decrease the risk of tunnel enlargement.

A group of 25 patients underwent ACL reconstruction with compaction drilling in creation of tunnels, consecutively. The remaining 33 patients whose operations were performed with extraction reaming were evaluated as the control group. The aim of this study is to investigate whether the bone impaction affects tunnel enlargement by comparing both groups and examining the correlation between radiological and clinical results of the operation after a minimum 2 years of follow-up.

Materials and methods

Patients

The records of 58 patients treated with arthroscopic ACL reconstruction between 2004 and 2005 were collected retrospectively. According to request, 44 of 58 patients treated with the same technique and same implants except in tunnel constitution were taken for study. Patients whose operations were performed after a minimum 6-week interval (mean 7.8 weeks; 6–12 weeks) from initial trauma, were properly controlled and had a minimum follow-up of 2 years were included in study. The patients who underwent additional reconstructions (additional ligament ruptures, meniscus repair, chondral interventions) and multiple arthroscopic interventions were excluded.

Twenty-one patients, whose preferred surgical method was tunnel dilation with compaction drilling, were allocated to group A and further 23 patients with extraction reaming to group B as a control group.

Surgery

An arthroscopic procedure was performed for all patients to confirm ACL tear, status of articular cartilage, and meniscus pathology. In both groups, gracilis and semitendinosus tendons (GHT) were harvested through an anteromedial longitudinal tibial incision on pes anserinus. Graft preparation and tunnel positions were arranged [6]. In Group A, tunnel preparation was performed to 6 mm by using a drill, and the tunnel was enlarged up to 8–9 mm by using dilators with incremental sizes. In Group B, tunnels were prepared with high-speed drills. Graft fixations were the same for both groups: femoral fixation with transfixation (Transfix; Arthrex, Naples, FL), and tibial fixation with an interference screw and tendon staple (Arthrex). Diameters of interference screws were the same with drilled tunnel width.

Postoperative Care

All patients had been rehabilitated in the postoperative period with the program scheduled by Shelbourne et al. [22]. Closed chain kinetic exercises had been started at the very first postoperative day. No type of knee brace had been used in the postoperative period. Clinical testing included Lysholm knee score and the International Knee Documentation Committee (IKDC) rating and the anterior–posterior laxity was evaluated with the Lachman test.

Radiographic examination

Anteroposterior and lateral radiographs and multi-slice computerized tomography (MSCT) with a slice thickness of 2 mm were taken. Tunnel placements were also evaluated with plain radiographs and compared between the groups. In order to evaluate both femoral and tibial tunnel placements simultaneously, the sums of the percentages of femoral and tibial tunnel placements were scored according to the so-called ‘sum score of the graft placement’ [14] (Fig. 1).

Fig. 1 Tunnel placements

Enlargement of tunnels were evaluated based on measurements of diameters between inner sclerotic rims of the tunnels on the coronal and sagittal section taken at three different points of the femur and tibia; proximal (F1;T1), middle (F2;T2), distal portion (F3;T3) (Fig. 2). The measurements were scored blinded by an experienced radiologist with the same software of the same CT (Siemens GmbH; Berlin). The average values of femoral and tibial tunnel sizes and sclerotic changes at tunnel walls were recorded (Figs. 3 and 4).

Demographic and clinical scores and radiographic measurements of two groups were compared with parametric and non parametric tests (student *t*-test and Mann-Whitney *U*, respectively) pre- and postoperatively. Clinical scores of patients between pre- and postoperative evaluation were compared with Mann-Whitney *U*.

Results

Nineteen male and 2 female patients of group A with mean age 23.4 years (range 19–36 years) were followed for an

Fig. 2 The diameter of the tunnels were measured at the proximal (F1,T1), middle (F2,T2), distal portion (F3,T3) of the femur and tibia

Fig. 3 F2 Slice

average of 30.7 months (range 26 to 34 months), and 23 patients (20 males, 3 females; mean age 25.3; range 17–38 years) were followed for an average 39.4 months (range 35–46 months).

The mean Lysholm scores in group A increased from 51 (49–68) to 93 (61–100) and, in group B, from 58 (36–71) to 90 (52–100) ($p < 0.05$).

Preoperative IKDC scores were as follows: in group A, 13 patients abnormal, 8 patients severely abnormal; in group B, 15 patients abnormal, 8 patients severely abnormal. Postoperative IKDC scores were improved in group A to normal in 6 patients, nearly normal 11 patients and abnormal 4 patients. In group B, 7 patients were found

Fig. 4 T2 Slice

normal, 12 patients nearly normal, 3 patients abnormal and 1 patient severely abnormal.

In 2 patients, instability was detected, 1 in each group.

The sum score of the graft placement were 60.8 ± 11.4 in group A and 62.6 ± 13.4 in group B.

In group A, dilated initial tunnel diameter was 8.57 mm (range 8–9 mm). At the follow-up, the mean value of tunnel enlargement was 2.64 mm (range 0.5–4.27 mm) in coronal section and 2.38 mm (range 0.5–4.85 mm) in sagittal section at the femoral site; 1.64 mm (range 0.8–3.45 mm) in coronal section and 1.72 mm (range 0.5–3.3 mm) in sagittal section at the tibial site. In group B, drilled initial tunnel diameter was 8.73 mm (range 8–9 mm). The mean tunnel diameters were detected at 2.31 mm (range: 0.3–4.63 mm) in coronal section and 2.27 mm (range 0.3–4.5 mm) in sagittal section at the femoral site; 2.26 mm (range 0.5–4.5 mm) in coronal section and 2.40 mm (range 0.5–5.30 mm) sagittal section at the tibial site. There was no statistical difference between tunnel diameters between the two groups at the femoral site but significant difference at the tibial site ($p=0.00192$ for coronal; $p=0.0171$ for sagittal). There was no significant difference between the sum scores of the graft placement, either.

Both sclerotic changes around the tunnel were detected in 18 patients (86%) in group A and in 15 patients (65%) in group B.

There were no postoperative complications such as infection, deep venous thromboses, or nerve injuries.

Discussion

Bone tunnel enlargement following ACL reconstruction has become a topic of interest in the literature [3–5, 8, 9, 11–13]. The etiology and mechanism of this phenomenon is, however, not clear and may be multifactorial [15, 17]. Hoher et al. proposed that both biologic and mechanical factors are associated with tunnel widening [9]. Mechanical factors contributing to tunnel enlargement include stress deprivation of bone within the tunnel wall and graft-tunnel motion [16]. Biological factors associated with tunnel enlargement include inflammatory and immune response, cell necrosis due to toxic products in the tunnel, and heat necrosis as a response to drilling [17]. Tunnel wall quality may be an important factor considering tendon fixation using a tunnel fixation method. Conventional reaming (extraction drilling) removes bone and is designated as an extraction method. Dilation (compaction drilling) preserves bone by compacting the tissue along the sides of the tunnel. The effects of dilation of tunnels on the strength of hamstring graft fixation using interference screws were evaluated in two different cadaver studies. The investigators yielded in both studies significantly higher graft pull-out values for the dilated tibial specimens than for the reamed specimens with mechanical testing [1–3]. Rittmeister et al.'s study [21] concluded that the benefit of dilators was related to a better match of tunnel and graft size, than achieving good bone quality.

Table 1 Patient data

	Group A	Group B	Significance
Patients	19 males, 2 females	20 males, 3 females	
Age (years)	23.4 (19–36)	25.3 (17–38)	
Follow-up (months)	30.7 (26–34)	39.4 (35–46)	
Preoperative Lysholm Scores	51 (49–68)	58 (36–71)	NS
Postoperative Lysholm Scores	93 (61–100)	90 (52–100)	NS
Preoperative IKDC Scores	13 patients abnormal, 8 patient severely abnormal.	15 patients abnormal, 8 patient severely abnormal.	NS
Postoperative IKDC Scores	6 patients normal, 11 patients nearly normal, 4 patients abnormal	7 patients normal, 12 patients nearly normal, 3 patients abnormal, one patient severely abnormal.	NS
Lachmann test	1	1	NS
Sumscore of the graft placement	62.6 ± 13.4	60.8 ± 11.4	NS
Initial tunnel width (drilled diameter)	$8.57 (8-9) \pm 0.50$	$8.73 (8-9) \pm 0.45$	NS
Femoral enlargement coronal mm	$2.64 (0.5-4.27) \pm 0.15$	$2.31 (0.3-4.63) \pm 0.12$	NS
Femoral enlargement coronal %	30.83 ± 1.7	26.68 ± 1.44	NS
Femoral enlargement sagittal mm	$2.38 (0.5-4.85) \pm 0.14$	$2.27 (0.3-4.5) \pm 0.11$	NS
Femoral enlargement sagittal %	27.99 ± 1.6	26.22 ± 1.35	NS
Tibial enlargement coronal mm	$1.64 (0.8-3.45) \pm 0.06$	$2.26 (0.5-4.5) \pm 0.13$	$p=0.00192$
Tibial enlargement coronal %	19.1 ± 0.75	29.55 ± 1.31	$p=0.00192$
Tibial enlargement sagittal mm	$1.72 (0.5-3.3) \pm 0.07$	$2.40 (0.5-5.30) \pm 0.10$	$p=0.0171$
Tibial enlargement sagittal %	20.1 ± 0.8	27.64 ± 1.22	$p=0.0171$
Sclerotic changes around the tunnel	18 patients 86%	15 patients 65%	

Arnoczky et al. [1] have demonstrated insertion torque and pullout strength are increased by compaction drilling. In another biomechanical study using porcine bone, Nurmi et al. [19] found no difference between extraction and compaction drilling in initial fixation strength. In our study, tunnel diameters were similar at femoral and tibial sites. We suggested that the use of dilators may enhance bone quality at the tunnel walls and prevent tunnel enlargement at follow-up. To investigate this hypothesis, compaction drilling technique were performed in tunnel constitution in a group of consecutive cases. Despite lots of reported series on tunnel enlargement, there is no consensus or standardized values on the amount of the increased diameters at follow-up. Consequently, another group of patients operated with extraction reaming technique were taken as a control group.

CT scanning has been recommended for evaluating the dimensions of the bone tunnels. Compared to plain X-ray films, MSCT has the advantage that it does not depend on geometric factors that may influence measurement, such as a small change in knee positioning or in the exposing distance from the film surface [10, 12, 13]. We decided to use MSCT images because this technique depicts the real boundaries of the trans-osseous tunnel more exactly.

Magnetic Resonance Imaging (MRI) is unable to determine the bone tunnel border due to a positive echo of the adjacent bone. However, Hoher et al. [9] and Fules et al. [7] calculated cross-sectional area (CSA) perpendicular to the long axis of the tibial tunnel digitally at three levels using MRI, and they found a mean CSA tibial tunnel enlargement of 33%. They concluded that a direct CSA measurement provides a highly accurate method of tunnel assessment. We were not able to use MRI study because of cost effectiveness.

The phenomenon “tunnel enlargement” is important when considering using intratunnel fixation devices. There are other parameters like tunnel placement associated with tunnel enlargement [9, 11]. After comparison of clinical scores and the sum scores of the graft placement, with statistical analyses showing any significant difference, patients were taken to examination with MSCT. Compaction drilling yielded better results in aspect of tunnel enlargement, and this may have occurred during initial placement of interference screw or as a biological process in the follow-up period. The radiographic and clinical data of the present study are the result of the final follow-up evaluation, we did not have initial CT measurements which may be the weakest point of our study.

Tunnel enlargement was first reported by L’Insalata et al. [16]. They observed an increase of $20.9\% \pm 13.4\%$ in the anteroposterior (AP) radiographs for the tibial tunnel and $30.2\% \pm 17.2\%$ for the femoral tunnel; $25.5\% \pm 16.7\%$ for the tibial tunnel and in the lateral view, $28.1\% \pm 14.7\%$ for

the femoral tunnel after ACL reconstruction. Nebelung et al. [18] observed similar findings with hamstring tendon grafts at 2 years follow-up.

Iorio et al. [11] observed the rate of tunnel widening seems to be lower than that reported in previous studies using different techniques. They concluded that using an anatomical fixation with stiff and strong fixation devices combined with a less aggressive rehabilitation program could contribute to minimizing tunnel enlargement after ACL reconstruction with doubled hamstrings. Other reported series with different time periods showed the increase in the width of the tunnels from 6 weeks up to 2 years [5, 12, 20, 21]. In the current study, measurements of tunnel diameters taken in a follow-up period after 2 years were found in similar ranges to reported series in the literature (Table 1).

Yoshiya showed that tunnel walls converted from cancellous bone to cortical-like structure or pseudo cortex in follow-up [25]. Klein et al. [15] have classified morphologic changes and also defined four subtypes. In finite element analysis, most of the tension stresses were found at posterolateral side of tunnel walls, where Au et al. [2] expected sclerotic changes according to Wolf’s law. In our study, these sclerotic changes were observed in 86% patients of group A and 65% patients of group B.

Conclusion

Unexpected periarticular bone loss with enlarged tunnels has the potential to cause problems with graft positioning, and fixation is a concerning clinical situation in revision ACL surgery. Compacted tunnel walls may resist enlargement, and we suggest this technique produces better tunnel diameter values especially with intratunnel fixation implants.

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