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EVALUATING FEMORAL TUNNEL WIDENING IN ACL RECONSTRUCTION: A CT-BASED COMPARISON OF TIGHT ROPE RT, TRANSFIX, AND BIOSCREW FIXATION METHODS

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ABSTRACT This prospective study evaluates femoral tunnel widening in ACL reconstruction among 100 male patients aged 20-40, using three femoral fixation methods: Transfix, Tight rope Reverse Threaded (RT), and Bioscrew. All patients had a tibial fixation with a Bioscrew and were assessed using Computed Tomography (CT) at 2 weeks, 6 months, and 1 year postoperatively. Clinical outcomes were measured using the IKDC 2000 Subjective Knee Evaluation and Lysholm Knee Scores. Of the 86 patients followed beyond 1 year (average follow-up: 28.26 months), 81.4% returned to their original professions. Significant improvements were observed in both clinical scores across all groups, with no significant inter-group differences. CT scans revealed progressive tunnel widening predominantly in the first 6 months, with the Tight rope RT group showing significant aperture dilatation compared to other groups. These results suggest that while clinical outcomes do not significantly differ among fixation methods, the Tight rope RT device leads to greater tunnel widening at the aperture, highlighting the need for further investigation into long-term implications and revision surgery challenges. Tunnel widening is thus an integral finding in ACL reconstruction, with the majority occurring within the first 6 months post-surgery.

KEYWORDS : ACL reconstruction, femoral tunnel widening, femoral fixation methods, Computed Tomography, clinical outcomes, prospective study.

INTRODUCTION

ACL (Anterior cruciate ligament) reconstruction is a fairly popular procedure, routinely performed in almost all parts of the world. Yet, the failure rate after ACL reconstruction performed in the hands of even expert surgeons is estimated to be in the range of 10–15%, and only 60% of patients undergoing this surgery can resume sporting activities [1]. Hence, there has been continuously evolving research in an attempt not only to identify the technical fallacies and reform the technique but also to make revision surgery easier and more productive in failed cases.

Tunnel widening after ACL reconstruction is a well-described phenomenon seen in all cases regardless of the grafts or the technique used. However, reports vary with the extent of widening with different fixation methods. With an aetiology that can rightly be termed multifactorial, the clinical implications of this phenomenon on the results of ACL surgery, even today, largely remain unknown. However, the fact that wide tunnels pose difficulty in revision surgeries necessitating grafting is well recognized [2-4]. This could especially be crucial on the femoral side, where the more important entry point might be compromised because of inadvertent widening noted during revision surgery [1].

The purpose of our study was to evaluate the incidence and properties of femoral tunnel widening in young and active patients undergoing ACL reconstruction with quadrupled hamstring graft with fixation on tibial side performed with a Bioscrew (Arthrex, Naples, FL) while femoral fixation performed with either a Tight rope Reverse Threaded (RT) (Arthrex, Naples, FL) or Transfix (Arthrex, Naples, FL) or another Bioscrew (making a double interference screw construct). Since the extent of widening linked to different fixation methods is still a matter of debate, we aimed to determine the influence of three different fixation methods on femoral tunnel widening, with a Computed Tomography (CT) scan employed to measure tunnel diameter to increase the accuracy and minimize intra-observer and inter-observer errors [5]. To the best of our knowledge, very few studies are published in the literature employing CT scans for evaluation that provide a comparative analysis of tunnel widening with all routine modes of graft fixation, especially the Tight Rope RT device.

MATERIAL & METHODS

Our institute's prospective study involved 100 consecutive patients who underwent single bundle ACL reconstruction from January 2008 to March 2012. 86 out of these were available with us till the final follow-up. These were divided into three groups based on the femoral fixation method (Group I – Transfix; Group II – Tight rope RT; Group III – Bioscrew). We allocated the patient to a particular group after receiving informed consent. In all cases, fixation on the tibial side was performed with a Bioscrew (Arthrex, Naples, FL). Only 20-40 years old males with unilateral ACL rupture less than a year old, diagnosed clinically and confirmed radiologically by Magnetic Resonance Imaging (MRI), were selected for the study. Patients with meniscal tears requiring meniscal repair, cases of a multi-ligamentous knee injury, patients with a history of previous knee surgery, mechanical or anatomic mal-alignment, and arthritic changes more than grade 3 on x-ray (Kellgren and Lawrence classification) were excluded from the study.

Surgical technique

First, a diagnostic arthroscopy was performed, and the findings were confirmed. Next, semitendinosus and gracilis tendons were harvested by an oblique incision measuring 3.5 cm over the pes anserinus. The arthroscope was reinserted, and the tibial tunnel was drilled at the ACL footprint using a drill guide fixed at 55°. Tunnel preparation was done with standard instrumentation with a diameter corresponding to the quadrupled graft. A femoral tunnel was made through an AM portal in the Tight rope and Bioscrew groups (Groups II and III, respectively).

In contrast, a transtibial technique was used in all cases in the Transfix group (Group I). The pre-tensioned graft was first fixed on the femoral side with the decided fixation mode per the patient's allocation into a specific group. After evaluation for graft impingement, cyclic loading was done. The graft was manually tensioned at 30° of knee flexion. The tibial side was fixed with a Bioscrew (Arthrex, Naples, FL) measuring 25 to 30 mm in length and diameter 1 mm larger than the tunnel diameter. Three of our patients required notchplasty.

Postoperative rehabilitation

A similar rehabilitation protocol was followed in all cases under the strict supervision of our physiotherapy team. Immediately after surgery, the knee was supported by an extension knee brace. Isometric quadriceps exercises started the day after the surgery, and progressive weight bearing was encouraged using crutches with progression as tolerated. Two weeks after surgery, stitch removal was done, only nighttime brace wear was recommended for another 2 weeks, and active range of motion (ROM) exercises were started to achieve flexion greater than 90° by the end of the sixth postoperative week. Patients were advised to ride exercise bicycles at 8 weeks and to perform gymnasium exercises by 12 weeks. Closed kinetic chain and isometric quadriceps-strengthening exercises were continued during the first 3 months; after that, patients were encouraged to return progressively to their normal functional activities. Running was allowed simultaneously, with a return to professional sporting activities permitted after 6 months.

Follow-up and evaluation

All patients were evaluated clinically and radiologically at follow-ups of 2 weeks, 1 month, 3 months, 6 months, and 1 year, and every six months after that.

Clinical Evaluation

Detailed clinical examination and functional assessment were performed at every follow-up with the International Knee Documentation Committee (IKDC) 2000 Subjective Knee Evaluation score [6] and the Lysholm Knee Score [6], and a comparison was made with the preoperative status.

Radiological evaluation

Apart from routine X-rays, a non-contrast 2-D CT scan of the operated knee was obtained on a helical multi-detector scanner. Oblique coronal and sagittal images were acquired at 130 kV and 60 mA, with a slice thickness of 1 mm. The collimation used was 0.5 mm. Scans were performed at 2 weeks, 6 months, and 1 year postoperatively. The data acquired in the second week was considered baseline data and used for comparison with those acquired at 6 months and 1 year.

Bone tunnel diameters were measured perpendicular to the axis of the tunnels in the oblique coronal and sagittal planes by an independent experienced radiologist. The diameter of the tunnels was measured at three points: -

1. Aperture (A),
2. Just below suspension points in Group 1 and 2 and for Group 3, just distal to the tip of Bioscrew (C)
3. A point mid-way (B) between points (A) and (C) Tunnel widening noted was graded as suggested by Nebelung et al. [7]: no enlargement, 0 to 0.5 mm; borderline enlargement, 0.5 to 2.5 mm; clear enlargement, 2.5 to 4.5 mm; and massive enlargement, 4.5 mm or greater.

Sagittal section

Coronal section

Statistical analysis

The unpaired T-test was used to analyze the difference of means for parametric data, and a P value < 0.05 was assumed to be statistically significant. The Wilcoxon signed-rank test was performed to evaluate the significance of clinical outcome statistically by Lysholm and IKDC 2000 Subjective Knee Evaluation scores for all groups. The resulting $P < 0.05$ was accepted as a statistically significant difference in the median of paired observations.

RESULTS:

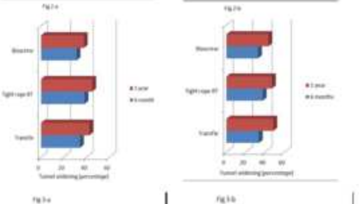
This prospective study included 100 patients, of which 86 were available for follow-up beyond 1 year, the average follow-up being 28.26 months (range 23-38 months). The mean age of our patients was 28.6 years. 54.5% of our patients were elite sportsmen, the majority being wrestlers. Almost 20% professionally were working with defence/ security forces. The mean duration from their time since injury to their surgery was 116 days (23- 279 days). The subjects were allocated into Group I-III (Group I- 32 patients, Group II- 28 patients, Group III- 26 patients) based on the femoral fixation method they had opted for after informed consent. All groups were statistically analyzed, both clinically as well as radiologically, to reveal the following results: -

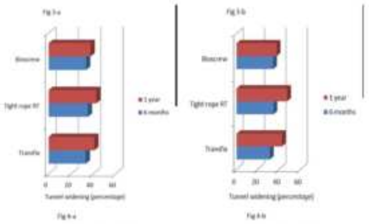
Clinical evaluation

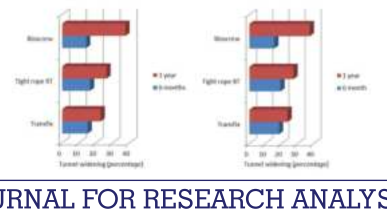
At the end of 1 year, 81.4% of our patients had returned to their original profession. The Lysholm knee score improved on average by 35.63 points (range, 22 to 48) in the Tight rope RT group and 36.77 points (range, 23 to 56) in the Transfix group and 38.93 points (range, 30 to 61) in the Bioscrew group compared with the preoperative values. The IKDC 2000 Subjective Knee Evaluation score also improved by a mean of 37.3 points (range, 33.41 to 45.72) in the Tight rope RT group and by 41.33 points (range, 32.53 to 56.34) in the Transfix group and by 40.32 points (range, 33.56 to 55.87) in Bioscrew group. On statistical analysis, the postoperative improvement in all functional scores was significant (p-value < 0.001 for both functional scores). However, on the inter-group comparison, the difference in functional scores at 1 year was statistically insignificant (p-value 0.231 and 0.337 for Lysholm and IKDC scores, respectively), implying all three forms of fixation to be equally efficacious clinically.

CT evaluation

Average widening noted at the three points (A, B and C) for Groups 1,2,3 at 6 months and 1-year follow-up in both the oblique coronal and sagittal images has been graphically depicted in Figures 2-4. In the intergroup comparison, there were no significant differences between the three groups regarding femoral tunnel dilatation that occurred at either points B or C at the end of 1 year. However, the dilatation at the aperture was significantly higher in the Tight rope RT group than in the other two groups (p-value 0.019 and 0.021 for sagittal and coronal images, respectively).







Complications

There were no postoperative complications of infection, deep vein thrombosis, or nerve injury. No gross abnormalities regarding laxity or alignment were noted that would demand a revision. Two cases had flexion of less than 120° at the end of 6 months, which required manipulation under anaesthesia.

DISCUSSION

Tunnel widening after ACL reconstruction is a proven adverse finding known for a long time. In 1990, Jackson et al. [8] mentioned cystic changes in the bone tunnels after ACL reconstruction with bone-patellar tendon-bone allograft. Later, in 1997, L'Insalata et al. [9] observed tunnel widening with hamstrings. Tunnel enlargement has also been reported using prosthetic ligaments [10]. Although the clinical impact of this phenomenon on graft incorporation has not yet been proven, most authors believe there is no correlation between tunnel widening and at least the early functional outcome (up to 2 years) [3,11-13]. However, tunnel widening may complicate revision ACL surgery, posing technical challenges with possible compromise of graft placement, fixation and incorporation, necessitating the need to perform bone grafting of the enlarged bone tunnels as the first stage of a 2-stage procedure [2-4,11]. Hence, there is an interest in looking for measures to minimize it.

The basis of tunnel widening is multifactorial, with several possible mechanical and biological contributing factors [11-13]. Biomechanical causes include the excess motion of the graft in the bone tunnel (the bungee-cord effect and the windshield-wiper effect) redirecting the forces at the tunnel entrances or poor bone quality in patients but the surgeon following an accelerated brace-free rehabilitation protocol that places high demand on the unincorporated ACL grafts. Biological causes, on the other hand, include surgery-induced increased levels of osteolytic cytokines (interleukins 1 , bone morphogenetic proteins, tumour necrosis factor and nitric oxide) in the synovial fluid, leading to accelerated bone resorption. This may be especially relevant in cases with resorbable implants, improper tunnel positioning or screws protruding to the joint line because synovial fluid in these situations can track between the graft and the bone tunnel wall [14]. Additionally, widening may depend on graft choice [15,16]. Tunnel widening is greater with hamstring grafts than with patellar tendon autografts. This has been attributed to the longer time required for soft tissue–to–bone healing and the lower stiffness of hamstring fixation techniques [17, 18]. Since quadrupled hamstrings are a common choice nowadays for surgeons worldwide, we were interested in studying this phenomenon in hamstring reconstructed ACLs to find possible ways to decrease tunnel widening using hamstring autografts.

It is generally agreed that tunnel widening mostly occurs in the first year after surgery and then gradually plateaus. Dyer and Elrod [19] observed tunnel widening in the first 6 months. Fink et al. [20] noted that the greatest widening occurs within the first 6 weeks. Peyrache et al. [21] found tunnel widening to occur early in the first three months and then stabilize for the next two years, after which, conversely, tunnel diameters mildly decrease. Following these reports, we assessed the values at 6 months and 1 year post-surgery duration, which seemed most logical. Like most authors, we also found a progressive increase in tunnel diameters in all groups till 1 year, with most widening confined to the first six months when the graft is unincorporated. After six months, the graft will likely incorporate and widen plateaus.

Hence, a possible factor that can minimize tunnel widening is thought to be rigid fixation. Attaining rigid fixation is supposed to minimize elongation (bungee effect) and prevent failure at the graft fixation sites during the cyclical loading of the knee before the biological incorporation of the ACL graft [22,23]. Because Tight Rope RT, Bioscrew and Transfix are popular and well-established femoral-side fixation methods that provide stable fixation, we used this comparative analysis to study the outcome. Since the femoral tunnel entry point is more crucial practically [1,24], the fixation method on the tibial side was kept similar in all three groups to ensure a more reliable comparison on the femoral side.

In all cases, CT scans in the second week showed almost uniformly cylindrical tunnels on the femoral side. Also, the measured tunnel diameters at 2 weeks of CT scan images nearly matched the reamer diameters used at surgery in all three groups. However, in the sixth month, the femoral tunnel diameters showed a progressive increase at all points, in both coronal and sagittal CT sections, with maximum tunnel dilatation being at the aperture in Transfix and Tightrope RT group while it was at point B for the Bioscrew group. At the end of 1 year, the tunnels in the Tight rope RT group had become funnel-shaped with maximum dilatation at the aperture except in one case where they were barrel-shaped. However, in the Transfix group, the shape remained nearly cylindrical.

In contrast, in the Bioscrew group, they were barrel-shaped in most cases, with maximum dilatation at point B. The dilatation at the aperture was greater for the transfix group than the bioscrew group, although not statistically significant. Still, the dilatation at the aperture was statistically significant for the Tight rope RT group likely because the far suspension point allows greater graft motion at the aperture point. Fauno and Kaalund [16] compared tunnel widening between the EndoButton and the Transfix at 1-year follow-up on radiographs and found more widening with the EndoButton (47.2% of cases in the EndoButton group and 17.07% of cases in Transfix group had tunnel enlargement 2 mm on femoral side). However, these findings contrast with Sabat et al. [25], who observed significant widening in the EndoButton group at the aperture and in the middle compared to the Transfix group only in oblique sagittal sections. The difference could be due to the difference in the sample size or the rehabilitation protocol.

Aperture fixation is more rigid and is hypothesized to have a role in decreasing tunnel widening [3,4,11,16,25,26]. Cheung P et al. [27] reported that we also observed relatively less tunnel dilatation at the aperture in the Bioscrew group compared to other groups. This could likely be because the interference screw provides a more rigid fixation that minimizes graft motion at the aperture. Maximum tunnel dilatation in this group was at the midway point (B).

As reported by various authors, average widening has been quite variable, ranging from 30.1% to 100.4 % [3,5,7,11,13,16, 18-20,27,28] after single bundle ACL reconstruction. The tunnel widening on the femoral side we observed was relatively on the lower side of these values, likely for a few reasons. First and foremost, conventionally, most authors have used digital radiographs, which are not as accurate as CT scans. CT scan has several distinct advantages. It does not depend on geometric factors such as changes in knee positioning or exposure distance from the film. It delineates boundaries more clearly, especially in the early postoperative period when tunnels are not apparent on radiographs. It has a much higher inter-observer and intra-observer reliability [5,11]. Secondly, we employed a 2-week postoperative CT scan as a baseline instead of the diameters of the reamers used intra-operatively. This already incorporates all widening that has occurred during surgery which could be due to oblique drilling, reamer toggling or interference screw insertion or due to accelerated rehabilitation in the early postoperative period.

The main drawback of our study was the relatively short-term follow-up, which precluded us from making comments on further behaviour of this phenomenon after 1 year and correlating this phenomenon with clinical results on a long-term basis.

CONCLUSIONS

Tunnel widening is an integral finding in all ACL reconstructions. Most of the widening occurs in the first six months, although it's progressive until one year. The authors believe there is no significant difference between the three different fixation modes in tunnel enlargement except with the Tight rope RT device, which leads to statistically significant dilatation at the aperture. The clinical implication of this phenomenon, however, remains doubtful.

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