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Assessment of Femoral Tunnel Length and Position in ACL Reconstruction Techniques and its Effect on Stability

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Abstract

Background: The Transtibial (TT), anteromedial portal (AMP), and all-inside (AI) techniques are frequently used in anterior cruciate ligament reconstruction (ACLR). However, there is an ongoing debate over which procedure is superior.

Aim of Study: This study Aimed to compare the functional and radiological outcomes following ACLR using these techniques.

Patients and Methods: Thirty active adult patients with symptomatic anterior cruciate ligament (ACL) injury were randomly assigned into three equal groups. The first group was treated using the TT technique. The Second and third groupswere managed using theAMP and the AI techniques respectively. All groups had the same postoperative course and were followed for 1 year after surgery. Functional outcomes were assessed using the International Knee Documentation Committee (IKDC) subjective knee evaluation score. Radiological assessment of the femoral tunnel length and position was documented. Results were evaluated and compared between all groups.

Results: This study showed statistically significant postoperative improvement in the subjective IKDC score in all groups, however there was no statistically significant differences between all groups. The TT group showed the largest Femoral graft angle (FGA) with a mean of 62.96±7.71 SD, while the AI group had the smallest FGA with a mean of 40.43±5.97 SD, and this was statistically significant (*p*-value <0.001). The largest graft inclination angle (GFA) was found in the AI group with a mean of 30.81±9.67 SD, while the TT group had the smallest GFA was in the TT group with a mean of 12.46±4.61 SD, and this was statistically significant (*p*-value <0.001). The AM group had the most posterior femoral tunnel position with a mean of 33.42±7.01 SD, while the most anterior femoral tunnels were found in the TT group with a mean of 36.03±8.14 SD, showing no statistically significant differences. The AMP group had the most distal FT position with a mean of 26.09±7.24 SD, while the most proximal FT were found in the TT group with a mean of 4.66±6.93 SD, showing statistically significant differences (*p*-value <0.001). The shortest femoral tunnel was found in the AI group with a mean of 32.24±3.67 SD, while the longest femoral tunnel was present in the TT group with a mean of 41.98±2.94 SD, showing statistically significant differences (*p*-value <0.001).

Conclusion: The AMP technique is a reliable method in ACLR with good functional outcomes, and better radiological results than the TT and the AI techniques regarding the femoral tunnel length and position. The AI technique is a good alternative ACLR method with more bone preservation and comparable outcomes to conventional ACLR surgeries.

Key Words: *Anterior cruciate ligament – Reconstruction – Transtibial technique – Anteromedial portal technique – All-inside technique– Femoral tunnel.*

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Introduction

ANTERIOR cruciate ligament (ACL) injury is common inathletes [1]. ACL deficitknee can result in high morbidity and long-term disability if inadequately treated [2]. Surgical treatmentis considered the treatment of choice in almost all active patients due to the frequent failure of nonsurgical management of ACL injuries. The purpose of anterior cruciate ligament reconstruction (ACLR) is to restore intact knee stability and normal knee kinematics [3]. Correct placement of both femoraland tibial tunnels is crucial to prevention of surgical failure. The femoral tunnel position influences not only knee kinematics but also graft length much more thanthe tibial tunnel position [4,5].

Several techniques have been described for ACLR including the trastibial(TT), anteromedial portal (AMP), and the all inside (AI) techniques.

The TT technique has been the most popular technique for creating the femoral tunnel during ACLR over the past two decades. The TT technique facilitates non-anatomical but isometric single-bundle reconstruction, and many authors reported satisfactory results with this technique. However, the TT technique has a tendency to produce the femoral tunnel in a non-anatomic location and the graft may be placed too far anteriorly and vertically.

Non-anatomical graft placement is the cause of graft failure, rotational instability, and limited ability to restore normal kinematics of the knee joint [6].

In the TT technique, the site of the femoral tunnel is guided by the tibial tunnel while the anteromedial portal AMP technique provides the surgeon with a higher freedom to position the graft in the anatomical position without being influenced by the tibial tunnel [7,9].

AI technique has been acclaimed to be an alternative ACLR technique. It uses sockets in a half-way tunnel ratherthan full tunnels, resulting in a reduction in the postoperative pain, swelling, and likelihood of synovial fluid flow or infiltration among the space between the graft and the bone interface [10,11]. Furthermore, the sockets can also prevent tunnel enlargement and accelerate graft maturation due to the eradication of dead space [12]. The aim of this studyis to compare the functional and radiological outcomes following ACL reconstruction using the TT, AMP, and AI techniques.

Patients and Methods

Thirty patients who were managed with an arthroscopic ACLR were included in this randomized prospective. Ten patients were treated using the TT technique in group 1, 10 patients underwent AMP technique in group 2, while 10 patients had ACL reconstruction using the AI technique in group 3. Informedconsent was obtained from all patients. The random assignment of all patients to enter either group was computerized using simple randomization. Diagnosis confirmation was based on the patient history, clinical examination, and radiological assessment by plain radiographs and magnetic resonance imaging (MRI).

The inclusion criteria were: Young, active patients with single knee ACL injury and symptomatic functional instability. The exclusion criteria were: (1) Skeletally immature patients. (2) Presence of osteoarthritis of the ipsilateral knee. (3) Patients who wereunfit for surgery due to a medical comorbidity. (4) Patients who had concomitant posterior cruciate ligament, collateral ligament injuries, or complex meniscal injuries that need meniscal repair.

All participants in this study were males with a mean age of 30.30±6.25 (SD), 25.80±5.45, 24.10±5.57 years for the TT, AMP, and the AI groups respectively. The mean time interval to surgery (±SD) was 6.50±4.33, 4.30±4.29, 4.25±4.35 months for the TT, AMP, and the AI groups respectively. The mean (±SD) preoperative subjective IKDC scores were 41.15±7.94, 48.14±5.95, 41.45± 10.10 for the TT, AMP, and the AI groups respectively (Table 1).

Table (1): Patients demography.

	TT Group	AMP Group	AI Group	Test used	*p*-value
Age (years):					
Mean±SD	30.30±6.25	25.80±5.45	24.10±5.57	3.084	0.062
Range	21-39	20-35	20-38		
Sex:					
Male	10 (100.0%)	10 (100.0%)	10 (100.0%)	0.000*	1.000
Side:					
Left knee	4 (40.0%)	3(30.0%)	4 (40.0%)	0.287	0.866
Right knee	6 (60.0%)	7 (70%)	6 (60.0%)		
Time interval from injuryto surgery (Months):					
Mean	6.50±4.33	4.30±4.29	4.25±4.35	0.883	0.425
Range	2-12	1-12	1-12		
Subjective IKDC:					
Mean±SD	41.15±7.94	48.14±5.95	41.45±10.10	2.339	0.116
Range	31.03-55.17	42.52-60.9	25.2-58.6		

There were no preoperative statistically significant differencesbetween the 3 groups.

Patients were followed-up at 2, 6 weeks postoperative, then every 3 months for a year after surgery. Functional outcomes were assessed using the International Knee Documentation Committee (IKDC) score and were compared at 1 year postoperative [13].

Radiological assessment was done using standard anteroposterior and lateral radiographs at 2,6 weeks postoperatively, then at 1 year postoperative. A3 dimensional computed tomography (CT) scan of the knee was done at 3 months postoperative to assess femoral tunnel position using the quadrant method after digital subtraction of the medial femoral condyle.

Statistical analysis:

Data were analyzed using Statistical Program for Social Science (SPSS) version 20.0. Quantitative data were expressed as mean ± standard deviation (SD). Qualitative data were expressed as frequency and percentage.

A one-way analysis of variance (ANOVA) when comparing between more than two means. Independent-samples *t*-test of significance was used when comparing between two means. Paired sample *t*-test of significance was used when comparing between related sample. Chi-square (X^2) test of significance was used in order to compare proportions between two qualitative parameters. Pearson's correlation coefficient (*r*) test was used for correlating data. Probability (*p*-value) 0.05 was considered significant, 0. 001 was considered as h ghly significant. *p*-value >0.05 was considered insignificant.

Surgical technique:

Patients lie supine on the operation table after Spinal or General Anesthesia, followed by tourniquet application. A standard anterolateral and anteromedial portals were established. Gracilis and semitendinosus tendonswere harvested and fashioned in all groups. A #2 suture used to whip stich the ends of the grafts. The two tendons were folded over a #5 ETHIBOND suture in cases of TT, AM groups and were folded over the tight rope in cases of All inside group. After obtaining proper positioning of the femoral tunnel; a guide wire was drilled through the notch and out of the lateral femoral cortex except in cases of all inside group. Subsequently the femoral tunnel was drilled to a 30mm depth corresponding to the graft diameter.

Group (1): TT Group:

The femoral tunnel was placed with a measured knee flexion of 110°. The corresponding offset femoral tunnel was selected to leave 2mm of the posterior wall of the lateral femoral condyle. The clock-face position was carefully established at the 10-o'clock position (right knee) or 2-o'clock position (left knee). The femoral tunnel was drilled over the guide pin to a depth of 30mm (Fig. 1A,B).

Group (2): AM Group:

In the AMP technique, the femoral tunnel was position was done using a guide pin introduced through the AMP with the knee flexed between 120-135 degrees. Next, the femoral tunnel was reamed with a 4-milimeter drill over the guide pin and then the femoral tunnel was drilled appropriate to the graft diameter. Finally, a tibial tunnel was drilled in the center of the ACL tibial stump (Fig. 2A,B).

Group (3): AI Group:

AFlipCutter (Arthrex) was usedto create a “retrosocket” by outside in drilling using a modified anterolateral (AL) portal. The curved marking device with a sharp tip is then inserted through the lateral portal to determine and mark the center of the femoral ACL footprint. The Flip Cutter aiming device is inserted through the modified AL portal and positioned at the premarked anatomic femoral origin. With the knee flexed to 90, a 3.5mm femoral pilot hole was then created with the Flip Cutter by an outside-in drilling in a retrograde manner to produce a femoral retrosocket. This socketwas drilled to a depth of 20mm. The tibialretrosocket was createdusing a similar technique, with the tibial aiming JIG placed in the midbundle position. The tibial socket was drilled to a depth of 35mm (Fig. 3).

This study was conducted at Kasr Al-Ainy Hospitals from February 2013 – February 2015.

Results

Outcome functional:

This study showed statistically significant postoperative improvement in the subjective IKDC score in all groups (Table 2).

In this study, 90% of patients in the AMP and the AI groups, while only 50% in the TT group had a postoperative total objective IKDC score A (normal) (*p*-value 0.034).

Radiological outcomes in all groups are shown in (Table 3).

Table (2): Correlation between preoperative and postoperative subjective IKDC score in all groups.

Subjective IKDC	TT Group		AMP Group		AI Group	
	Mean	±SD	Mean	±SD	Mean	±SD
Preoperative	41.15	7.94	48.14	7.94	41.15	10.10
Postoperative	82.41	6.08	88.39	6.08	88.60	8.30
Men Diff	–41.26	7.57	–40.25	7.57	–47.15	9.09
Correlation	0.443		0.562		0.527	
t-test	–17.242		–18.869		–16.410	
p-value	<0.001		<0.001		<0.001	

Table (3): Comparison of radiological outcomes in all groups.

Radiological	Group 1 TT	Group 2 AMP	Group 3 A1	ANOVA	*p*-value
X-ray:					
FGA:					
Mean±SD	62.96±7.71	43.96±9.78	40.43±5.97	23.106	<0.001
Range	44.3-74	33.2-65.3	32-48.9		
GIA:					
Mean±SD	12.46±4.61	24.32±6.71	30.81±9.67	16.267	<0.001
Range	6.2-22	11.634.2	15.9-49		
CT after 3 months:					
FT. position (Horizontal):					
Mean±SD	36.03±8.14	33.42±7.01	33.45±3.69	0.523	0.598
Range	17-44.7	25.1-46.2	28.45-39.5		
FT. position (Vertical):					
Mean±SD	4.66±6.93	26.09±7.24	20.80±11.31	16.369	<0.001
Range	0-19.1	10-33.1	0-39.9		
FT. Length (mm):					
Mean±SD	41.98±2.94	33.64±3.05	32.24±3.67	26.492	<0.001
Range	36.4-44.5	25.7-35.6	25.4-35.3		
Range	0-2.9	0-3.04	0.5-3		

The TT group showed the largest Femoral graft angle (FGA) with a mean of 62.96±7.71 SD, while the AI group had the smallest FGA with a mean of 40.43±5.97 SD, and this was statistically significant (*p*-value <0.001). The mean graft inclination angle (GFA) was largest in the AI group with a mean of 30.81±9.67 SD, while the TT group had the smallest GFA with a mean of 12.46±4.61 SD, and this was statistically significant (*p*-value <0.001) (Bar Chart 1).

The horizontal FT. position was most posterior in the AM group with a mean of 33.42±7.01 SD, while the TT group had the most anterior FT with a mean of 36.03±8.14 SD, although the difference was not statistically significant (*p*-value 0.598). The vertical FT. position was most distal in the AMP group with a mean of 26.09±7.24 SD, while the TT group showed the most proximal vertical FT position with a mean of 4.66±6.93 SD, and this difference was statistically significant (*p*-value <0.001) (Bar Chart 4).

The shortest femoral tunnel was found in the AI group 3 with a mean of 32.24±3.67 SD, while the longest femoral tunnel was present in the TT group with a mean of 41.98±2.94 SD, showing statistically significant differences in the femoral tunnel length (*p*-value <0.001).

KT 1000 postoperative assessment of the sagittal stability showed no statistically significance between the different groups, however the postoperative Rolimeter assessment of the sagittal plane knee stability showed statistically significant differences between the different groups with best results in the AM group with a mean of 1.18±0.92 SD and the lowest results in the AI group with a mean of 2.04±0.78 SD (*p*-value 0.048).

This study showed significant Positive correlation between horizontal FT position and postoperative subjective IKDC only in the TT group (*p*-value 0.002), however the AM and the AI groups were insignificant (Table 4).

Complications:

The complications encountered in this study are shown in Table (5).

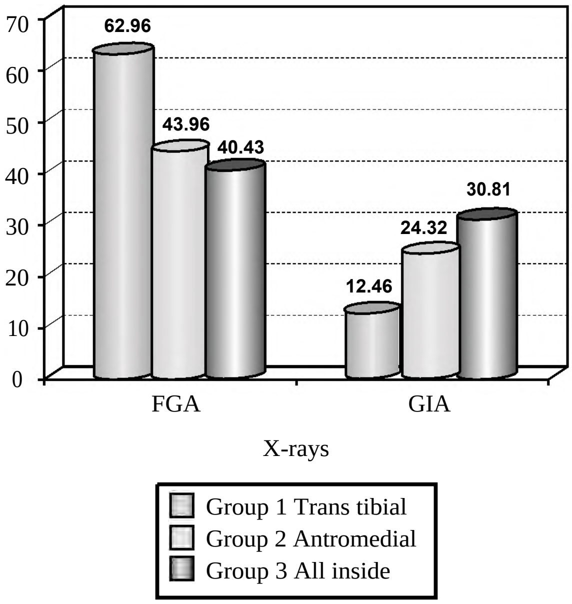
This study showed no statistically significant difference between all groups according to complications.

Table (4): Correlation between FT position and subjective postoperative IKDC in all groups.

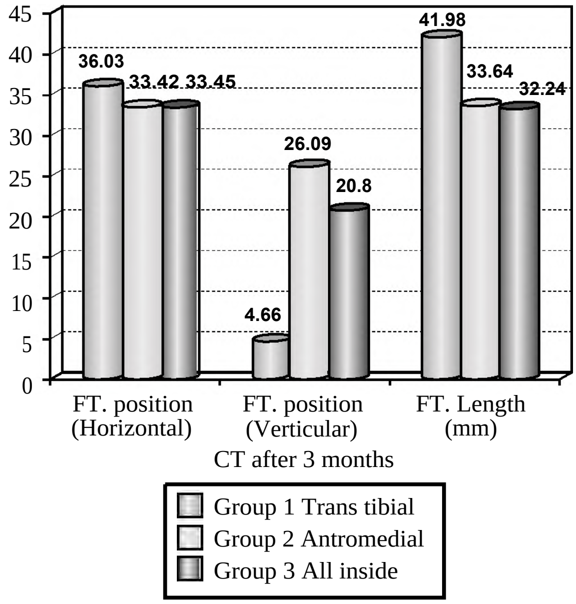
FT.position	Group 1 TT		Group 2 AMP		Group 3 A1	
	r	*p*-value	*r*	*p*-value	*r*	*p*-value
Horizontal	.854**	0.002	–0.055	0.880	–0.234	0.516
Vertical	–0.009	0.979	–0.079	0.828	–0.217	0.546

Table (5): The complications encountered in this study.

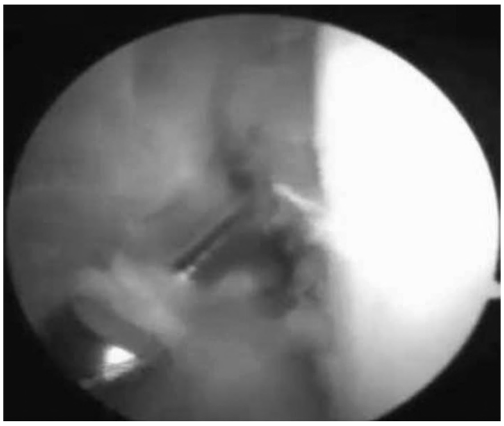
Complications	Group 1 TT	Group 2 AMP	Group 3 A1	X²	*p*-value
Intraoperative:					
- Impingement	0 (0.0%)	2 (20.0%)	1 (10.0%)	2.222	0.329
- NAD	10 (100.0%)	8 (80.0%)	9 (90.0%)		
Clinical:					
- Depp Venous Thrombosis	0 (0.0%)	1 (10.0%)	0 (0.0%)	4.071	0.396
- Ioss of motion flexion 90	0 (0.0%)	0 (0.0%)	1 (10.0%)		
- NAD	10 (100.0%)	9 (90.0%)	9 (90.0%)		
Graft rupture:					
No	10 (100.0%)	10 (10.0%)	10 (100.0%)	0.000	1.000
Fibrosis:					
- Cyclops	0 (0.0%)	2 (20.0%)	1 (10.0%)	3.320	0.506
- Mild arthrofibrosis	1 (10.0%)	1 (10.0%)	0 (10.0%)		
- No	9 (90.0%)	7 (70.0%)	9 (90.0%)		
Impingement:					
-Abnormal signal	4 (40.0%)	1 (10.0%)	1 (10.0%)	4.333	0.363
-Horizontal lie	1 (10.0%)	3 (30.0%)	2 (20.0%)		
-No	5 (50.0%)	6 (60.0%)	7 (70.0%)		
Effusion:					
-Minimal	3 (30.0%)	3 (30.0%)	3 (30.0%)	0.000	1.000
-No	7 (70.0%)	7 (70.0%)	7 (70.0%)		
Total complications:					
-Yes	6 (60.0%)	7 (70.0%)	5 (50.0%)	0.833	0.659
-No	4 (40.0%)	3 (30%)	5 (50%)		



Bar Chart (1): Comparison between FGA and GIA in all Groups.



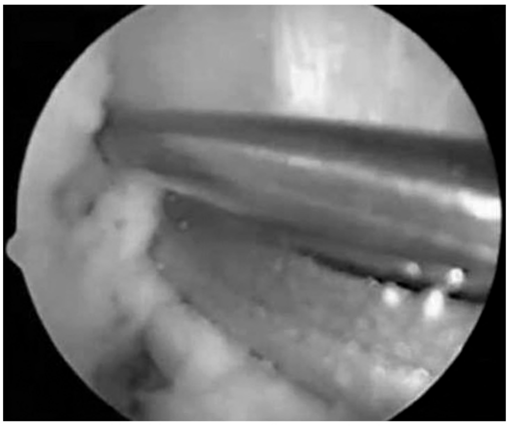
Bar Chart (2): Comparison between CT femoral tunnel position and length in all groups.



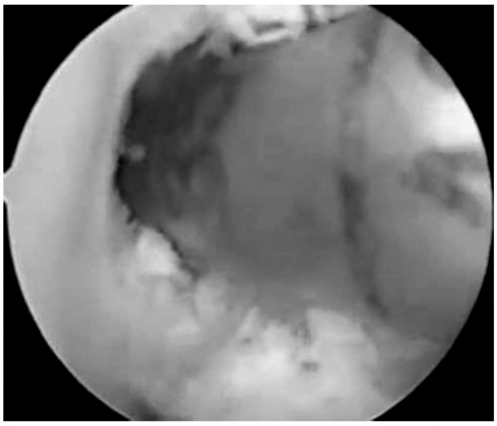
(A)

(B)

Fig. (1): (A) Guide wire entering the joint through the tibial tunnel into the femoral tunnel. (B) Drilling both tibial and femoral tunnels over the same guide wire.



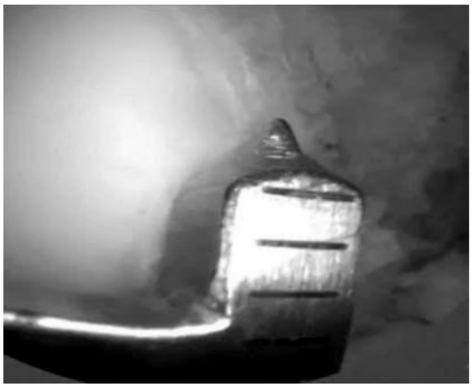
(A)



(B)

Fig. (2A,B): The femoral tunnel in AM technique.

Fig. (3): The measuring/marking device measuring high/low.



(A)


(B)


Fig. (4): FGA in (A) TT group and (B) AI group.

(A)


(B)


Fig. (5): Graft Inclination Angel GIA in (A) TT group and (B) AI group.

(A)

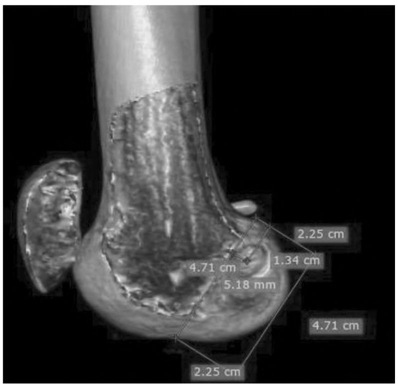

(B)


Fig. (6): 3D CT after digital subtraction of the medial femoral condyle, exposing the medial wall of the lateral femoral condyle, then applying the template of quadrant method.

Discussion

Biomechanical studies have emphasized the importance of anatomical tunnel placement during ACL reconstruction in order to restore normal knee kinematics and stability [14]. Transtibial drilling of the femoral tunnel during ACLR fails to restore normal knee kinematics, which in turn may lead to early-onset osteoarthritis [15]. An alternative technique for femoral tunnel preparation is the AMP drilling, in which independent drilling of the femoral and tibial tunnels is performed [16]. The AI technique, first published by Adrian J. Wilson et al., in July 2012, simplifies the process, with all work being carried out with the knee flexed to 90 degrees [15].

Our present study was conducted to assess and compare the femoral tunnel length and position using the previously mentioned techniques.

In this study, the FGA was largest in (TT) group and smallest in the AI group. Showing more horizontal femoral tunnel in the AI technique, while more vertical femoral tunnels were obtained in the TT technique. This was in line with the result obtained by Scopp JM et al., increasing the coronal plane obliquity of the femoral tunnel to the anatomic origin of the ACL restored rotational stability to the knee [4]. Comparing our results with the literature we can conclude that both the AMP and the AI techniques are offering higher obliquity of the reconstructed grafts which inturn offers more rotational stability than the TT technique. (Fig. 4A,B).

The GIA was largest in the AI group, while the smallest GIA was found in the TT group, showing more horizontal Graft orientation using the AI technique, while more vertical Graft orientation when using TT technique. Close result was detected by Ricardo H.Y., et al., as they concluded that the AI technique allowed positioning of the femoral tunnel such that the graft was more inclined and better clinical results were found regarding the pivot-shift maneuver [17] (Fig. 5A,B).

In this study, the AM group had the most posterior femoral tunnel position, while the most anterior femoral tunnels were found in the TT group, showing no statistically significant differences. The AMP group had the most distal FT position, while the most proximal FT were found in the TT group showing statistically significant differences.

The radiographic analysis with specific 3D CT scans (Tunnel coordinates were calculated using the Bernard-Hertel quadrant method) to define the Femoral Tunnel position recorded in our study (Fig. 6A,B) were also used by Fabrizio Matassi. et al., in their comparative study. Fabrizio Matassi et al., compared the functional outcomes and FT location using the TT and the AI techniques in ACLR, where they concluded that the FT position was in a location closer to the anatomical ACL footprint when using the AI rather than the TT technique [18].

A meta-analysis by Dae Hee Lee, et al., included all studies that used 3D-CT to compare femoral tunnel location, using quadrant method, following TT and anatomical techniques for single-bundle ACL reconstruction [19]. This meta-analysis showed near results between this study concluding that the use of the TT technique resulted in a higher, more shallow femoral tunnel aperture location than the anatomical techniques (Antromedial or All inside).

In addition, Kaseta MK, et al., also found that the TT technique resulted in more anterior and proximal placement of the guide pin compared with the transfemoral technique (All inside) [20].

Keller TC, et al., stated that the AMP or the AI techniques in ACLR are recommended over the traditional TT technique for creating an anatomical femoral tunnel [21-24].

Comparing the previous results to what we found in this study, the AI technique is offering a near anatomical position of the femoral tunnel compared to that with the TT technique.

This study showed that the shortest FT was found in the AI group, while the longest FT was present in the TT group, showing statistically significant differences.

Chong B.C., et al., stated the same results when they compared the TT and AMP techniques with respect tofemoral tunnel position and length [25].

In addition, Clockaerts S, et al., also found in their study that the length of the FT was larger in the TT technique compared to the AMP technique for ACL reconstruction [26].

Conclusion:

Anatomic ACL reconstruction resulted in the femoral tunnel length and femoral tunnel obliquity in the coronal plane being shorter and more oblique, respectively, as compared with nonanatomicACL reconstruction.

The AM portal technique provides more precise creation of the femoral tunnel guide and enhanced the ACL footprint visualization. The AI technique is a good alternative ACLR method with more bone preservation and comparable outcomes to conventional ACL reconstruction surgeries.

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تقييم النفق العظمى فى عظمة الفخذ فى الطرق المختلفة لاعادة بناء الرباط الصليب الإمامى وتاثيره على ثبات المفصل

قطع الرباط الصليبى الإمامى هى إصابة خطيرة ينتج عنها عدم الاستقرار فى الركبة فورا، وفقدان للموسم الرياضى بأكمله، وإعادة تأهيل طويلة وزيادة القابلية فى وقت مبكر للتعرض لالتهاب مفصل الركبة.

لا تزال التقنية الجراحية المثلي لإعادة بناء الرباط الصليبى الإمامى موضوعاً للجدل. وفقا للعديد من الدراسات التشريحية. مكان الرباط الصليبى الإمامى يكمن فى نقطة عميقة ومنخفضة على الجدار الأنسى من اللقمة.الفخذية الوحشية.

الموقف الصحيح من النفق الفخذ هو نقطة حرجة لنجاح واحد إعادة بناء الرباط الصليبى الإمامى.فى المستوى الجانبى يجب إن يكون النفق الفخذ فى الربع الخلفى من خط بلومنسات. فى السنوات الأخيرة، أظهرت العديد من الدراسات المزايا الميكانيكية من إعادة بناء الرباط بنفس زاوية ميل الرباط الأصلى فى المستوى الإمامى. وبالإضافة إلى ذلك، فقد تبين أنه مع نقص زاوية الميل تكون النتائج سيئة فى صورة استمرار تحول محور المفصل.

كثير من الجراحين عن غير قصد اعاد بناء الرباط موجه عموديا والذى قد لا يساعد على استعادة الخصائص الحركية والدائرية فى الركبة. وقد استشهد نفق الفخذ الرأسى باعتبارها واحدة من أكثر الأسباب شيوعا لفشل إعادة بناء الرباط الصليبى الإمامى. وغالبا ما يكون هذا النوع من الفشل فى صورة عدم الاستقرار فى المفصل واستمرار لتحول محور المفصل اثناء الفحص مع تحسن بنتائج إختبار لاخمان.

ولا يزال الحفر من خلال عظمة الساق الأسلوب الأكثر شعبية لعمل النفق الفخذى فى الرباط الصليبى الإمامى. مع هذه التقنية، وضع النفق الفخذى يعتمد على وضع نفق عظمة الساق، مما يؤدى دائما فى وضع عمودى نسبيا للرقعة المستخدمة فى اعادة البناء. على الرغم من أن النتائج السريرية الأولى لهذه التقنية جيدة، الا انه قد تبين ان وضع الرقعة يكون مخالف للوضع الصحيح تشريحيا. هذا فشل فى استعادة الخواص الصحيحية لمفصل الركبة، والتى بدورها قد تؤدى الى ظهور اعراض التهاب وخشونة سطح المفصل فى وقت مبكر.

تقنية بديلة لإعداد النفق الفخذى هى أمامى إنسى، التى يتم تنفيذ حفر الانفاق للفخذ والساق مستقلة كل على حدا. ويتطلب هذا النهج تقديرا الدقيق لتشريح عظمى داخل المفصل لتحديد وضع النفق.

فى الأونة الأخيرة، وقد تم إدخال مفهوم (التشريحية) أو (البصمة) لإعادة بناء الرباط الصليبى الإمامى. وقد تبين مع هذا المفهوم مزايا على إعادة البناء غير التشريحى.

هذه التقنية عبر الجانب الوحشى، نشرت لأول مرة فى يؤليو ٢٠١٢، تبسيط العملية، مع جميع الأعمال التى تقوم بها مع الركبة مثنى الى ٩٠. تصف هذه المذكرة الفنية عبر الجانب الوحشى بتقنية (كل من الداخل).

وهناك أدلة متزايدة على أن وضع التشريحى لنفق الفخذ فى إعادة بناء الرباط الصليبىالإمامى يمنح مزايا النشاط الحيوى على وضع النفق التقليدى.