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Indian Journal of Orthopaedics Surgery

Journal homepage: https://www.ijos.co.in/

Original Research Article

Short-term functional outcomes of anatomic single-bundle ACL reconstruction using modified I.D.E.A.L technique

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A R T I C L E I N F O

Article history:
Received 25-03-2022
Accepted 10-05-2022
Available online 15-06-2022

Keywords:
Anatomic anterior cruciate ligament (ACL) reconstruction
I.D.E.A.L technique
International knee documentation committee (IKDC) Score
Lysholm score
Tegner score

A B S T R A C T

Background: To achieve a satisfactory knee function and successful return to sports activities in patients with an ACL injury, it is essential to accurately reproduce the native ligament anatomy and biomechanics by placing the graft in the anatomical position within the ACL footprint. Our objectives are to investigate the short-term functional outcomes of an anatomic single-bundle reconstruction using the modified I.D.E.A.L technique of femoral tunnel placement, with 1-year follow-up.
Materials and Methods: A retrospective observational study of 120 patients who developed ACL rupture and underwent anatomic single-bundle reconstruction in TUY MALIK private hospital/ Sulaymaniyah city/Iraq from March 2020 till March 2022. The functional outcomes of the procedure were assessed using the subjective knee evaluation scores (IKDC, Lysholm, and Tegner scores) preoperative and 1-year postoperatively.
Results: The mean preoperative IKDC score was 50.96 (40.22- 60.91), and 1-year postoperative score was 83.81 (72.41-95.40), with a (p-value 0.000), whereas the mean Lysholm score was 51.17 (40-67) and 86.19 (75-95) preoperative and postoperative, respectively, with a (p-value 0.000). The mean Tegner score was 7.59 preinjury, while 3.63 before the operation and 7.18 after the operation with (p-value 0.000), representing a statistically significant enhancement in functional outcomes between preoperative and final clinical follow-up assessment.
Conclusion: Reconstructing ACL anatomically by placing the graft in the modified I.D.E.A.L position within the native femoral footprint can reestablish near-normal knee biomechanics, obtain unrestricted knee range of motion, and successful return to preinjury activity level.

1. Introduction

Sports activities are leading causes of Anterior Cruciate Ligament (ACL) injuries that may require surgery; approximately 80% of all knee ligament operations involved ACL surgery, making it among the most commonly performed procedures by sports surgeons all over the world.[1] An ACL injury can be deleterious, especially for a young athlete who may not be able to engage in demanding sports at a high level without surgical reconstruction. Furthermore, it can increase the long-term risk of developing knee osteoarthritis (OA).[2–4] The main objective of ACL reconstruction is to re-establish the normal knee biomechanics in patients with a functionally unstable knee. It is assumed that impaired knee biomechanics with the reconstruction procedure is the principal cause of long-term degenerative joint disease.[5,6]

ACL reconstruction techniques have progressed considerably over the last four decades. Initially, it was accomplished using an open technique to restore the ACL's

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https://doi.org/10.18231/j.ijos.2022.018

native architecture until the early 1980s, when technological innovations allowed for the development of arthroscopically assisted procedures. In 1990, the trans-tibial technique was developed, in which the femoral tunnel was established through the tibial tunnel; though this technique could restore the translational stability of the knee joint, follow-up of these patients revealed that they still exhibit rotatory instability.[5,7]

According to anatomical studies, ACL comprises anteromedial and posterolateral bundles corresponding to the tibial insertion sites.[5,8] Functional restoration of the injured ACL to its native dimensions, fiber orientations, and insertion sites on femoral and tibial sides is referred to as anatomic reconstruction.[9] The idea of recreating both bundles was first suggested in the 1980s to improve the rotational stability of the knee joint. However, several studies have compared the clinical results between anatomic double-bundle and single-bundle procedures showing that the double-bundle technique is not superior to the single-bundle technique in long-term follow-up.[10–13]

Improper graft placement is the principal cause of poor functional outcomes and early graft failure after ACL reconstruction.[14] Numerous research works have been conducted to further clarify the anatomical features and dimensions of native ACL footprint in an attempt to replicate these anatomical characteristics and obtain a more favorable clinical outcome,[15,16] as a consequence, many new surgical concepts have been developed including ˝complete footprint restoration˝ and ˝I.D.E.A.L techniques˝.[17,18] Our main objectives are to assess the functional outcomes of anatomic single-bundle reconstruction using the modified I.D.E.A.L femoral footprint positioning technique.

2. Materials and Methods

2.1. Study design and data collection

A retrospective observational study of 120 patients sustained ACL injury and underwent arthroscopic anatomic single-bundle reconstruction, using the modified I.D.E.A.L technique of femoral tunnel placement, in TUY MALIK private hospital/ Sulaymaniyah city/ Iraq, in the period from March 2020 till March 2022. Patients who met the inclusion criteria were enrolled, functional outcomes were assessed preoperatively and 1-year postoperatively using International Knee Documentation Committee (IKDC) subjective knee evaluation score, Lysholm knee scoring scale, and Tegner activity scale. All statistical computation was performed using the statistical method (SPSS 21); the data had been coded, tabulated, and presented in a descriptive form. The study was approved by the KBMS research protocol ethics committee. Informed consent was obtained from all participants in their native language.

The IKDC score was calculated, and the functional status of the knee joint was classified according to the total score into; poor (< 70), fair (70-79), good (80-89), and excellent (≥ 90). Regarding the Lysholm score, the maximum score is 100 points in which; (≤ 64) is unsatisfactory, (65-83) fair, (84-90) good, (91-100) is considered excellent. Tegner score comprises 10 levels; competitive sports form levels (8,9, and 10), competitive and recreational activities both combined in level 7, and “other recreational sports” constitute level 6. Levels (5 to 1) involve work and sports together, level 0 implies sick leave or disability as a result of poor knee function.

2.2. Exclusion criteria

1. Revision ACL reconstruction.
2. Fractures around the knee joint.
3. Multi-ligament knee injury.
4. Varus/Valgus knee malalignment.
5. Osteoarthritic changes (Kellgren and Lawrence type 3-4).
6. Inflammatory arthritis.

2.3. Preoperative evaluation

Relevant history was taken from all patients, followed by a thorough knee physical examination, concentrating on anterior and anterolateral rotatory instability tests. A plain radiograph and Magnetic Resonance Imaging (MRI) were taken to assess for the presence of any obvious bony abnormality, the pattern of ACL rupture, and any concomitant injury.

2.4. Surgical technique

A pneumatic tourniquet was applied on the proximal thigh, the limb was stabilized by a vertical post on the proximal thigh, and 2 horizontal posts were established on the bed to hold the knee in 90° and hyperflexion during the procedure (Figure 1 A). Prophylactic antibiotics (cefuroxime injection) administered within 30 minutes prior to incision. An oblique incision (3-4 cm) is made over the anteromedial aspect of the proximal tibia, approximately one inch medial and inferior to the tibial tubercle; Semitendinosus and gracilis tendons were identified and harvested (Figure 1 B).

Two main portals were established; standard anteromedial and anterolateral portals; a check scope was performed prior to ACL reconstruction for all patients; to confirm the ACL incompetency and assess other associated intra-articular pathologies such as chondral and meniscal injuries. Notchplasty, if needed performed with an arthroscopic burr through the anteromedial portal.

The lateral intercondylar ridge (Resident’s ridge) is a bony landmark that can be utilized to identify the anterior endpoint of the femoral footprint; Bifurcate ridge is another important osseous ridge that separates the

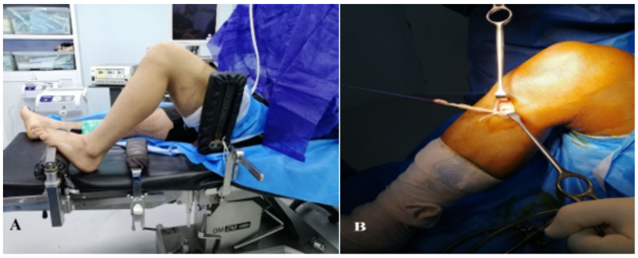

Fig. 1: A): Appropriate surgical positioning; **B):** Harvesting hamstring autograft.

insertion sites of anteromedial and posterolateral bundles within the footprint. The native ACL insertion site is oblong-shaped that attaches to the lateral intercondylar ridge anteriorly and extends to the lateral femoral condyle cartilage posteriorly.[17] (Figure 2).

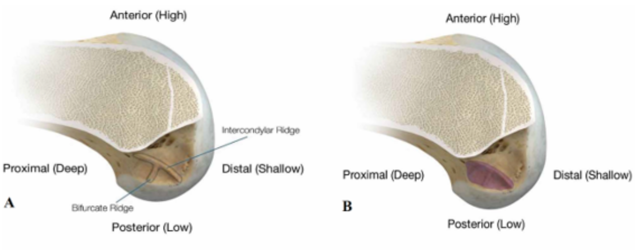

Fig. 2: A): Demonstrating the lateral intercondylar ridge and bifurcate ridge; **B):** Showing the native femoral footprint (purple-colored area)[17]

Through the anteromedial portal, a microfracture awl was placed 2-3 mm posterior to the lateral intercondylar ridge, posterior enough on the native footprint, leaving 1-2 mm bone bridge with the articular cartilage of the posterior aspect of the lateral femoral condyle in 90° of flexion, and introduced into the bone, creating a hole to reference the guidewire insertion. The joint was then hyperflexed, and the guide pin was drilled through the footprint toward the lateral epicondyle of the femur and out the skin on the lateral aspect of the femur. Reaming was then carried out initially with a (4 mm reamer), followed by an (8 mm reamer), creating a tunnel that crosses the anterior edge of the lateral intercondylar ridge 3-4 mm (Figure 3).

Through the same incision which was used for hamstring graft harvesting, the tibial tunnel was drilled in the standard anatomical position, the prepared graft (8 mm in diameter in most of the patients) was then passed under direct arthroscopic visualization, when the position was satisfactory, secured by an appropriate-size interference screw (anterior to the graft) or endobutton on the femoral side, and an interference screw on the tibial side. Finally, the arthroscope was reintroduced into the knee joint to check the final positioning and stability of the graft (Figure 4).

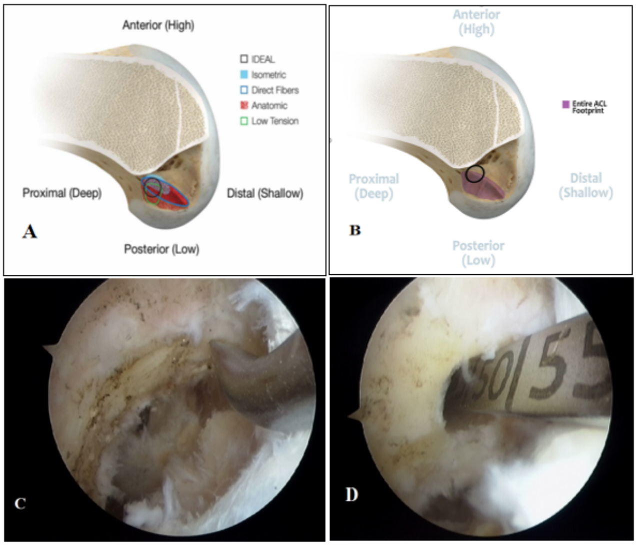

Fig. 3: A): The black circle indicates the IDEAL location of the femoral footprint.[17] **B):** The black circle demonstrates the modified IDEAL location of the footprint.[17] **C):** An arthroscopic view in which the modified I.D.E.A.L starting position is identified by a microfracture awl. **D):** Measuring the length of the prepared tunnel.

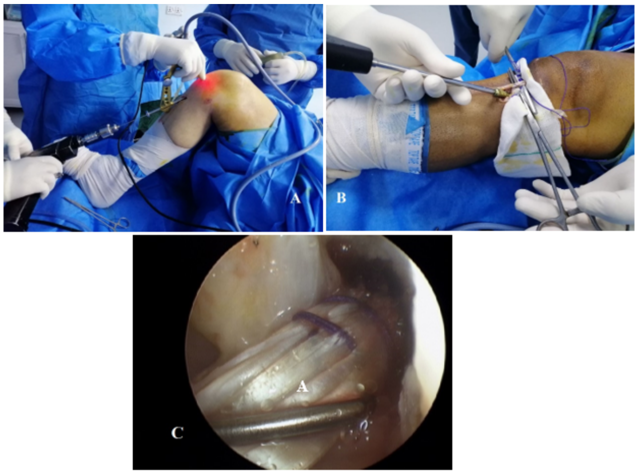

Fig. 4: A): Showing tibial tunnel preparation; **B):** Tibial side fixation of the graft by an interference screw; **C):** Checking the final position and stability of the graft

2.5. *Postoperative care*

All patients were discharged on the same day of the surgery; if there was no associated meniscal repair, full weight-bearing started on the same day using axillary crutches. The first postoperative visit was after 3 days, during which the surgical site was inspected, and the dressing was changed, appropriate imaging studies were taken to check and document the position of the graft and interference screws (Figures 5 and 6), and the physiotherapy program commenced, concentrating on, active range of motion and quadriceps isometric exercises. The second and third postoperative visits were after 2 weeks and 1 month, respectively.

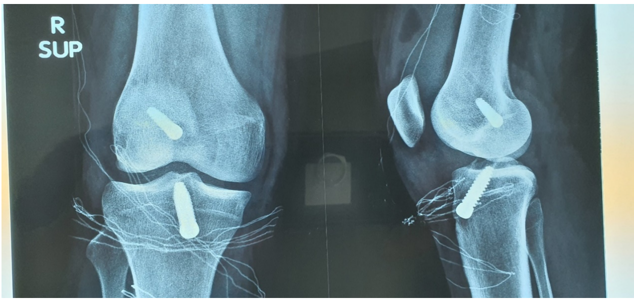

Fig. 5: Post-operative radiographic AP (left) and lateral (right) views after ACL reconstruction; showing position and orientation of the interference screws

Fig. 6: Postoperative sagittal and coronal MRI sections of the knee joint, demonstrating the position and orientation of the ACL graft and interference screws

3. Results

Demographic data of patients, which is summarized in (Table 1), illustrates that most of the patients were between 20-29 years old, which was 45% of the total, while 44.2% and 5.8% were between 30-39 years old and less than 20 years old, respectively. 95.83% of participants were male gender. Right side ACL rupture constitutes 58.3% of the patients, whereas 41.7% had left side injury. Regarding the activity level of the participants, 63.4% were recreational athletes. Then, 81.7% of injuries were sport-related injury mechanisms.

The mean IKDC score preoperatively was 50.96 and increased to 83.81 after the operation. While 51.17 and 86.19 were the mean of Lysholm score, Preoperative & Post-operative, respectively. Moreover, the Mean Tegner score before ACL injury was 7.59, while 3.63 preoperative and 7.18 post-operatively, indicating a statistically significant difference between (preoperative & postoperative) values in IKDC, Lysholm, and Tegner scores with a (P-value 0.000), as shown in (Tables 2 and 3).

We had shown here that all patients had poor IKDC scores before the operation, while in post-operative assessment, 65.8% of patients had a good score, and 13.3% demonstrated excellent scores. Moreover, 99.2% of the patients show unsatisfactory Lysholm score preoperatively, while postoperative score calculation demonstrates good outcome in 60.8% and excellent outcome in 14.2% of patients, representing a statistically significant difference between IKDC (P-value 0.000) and Lysholm (P-value 0.000) score values before and after the operation, as demonstrated in the (Table 4).

4. Discussion

Although many reconstruction techniques have been developed to recreate near-normal ACL anatomy and kinematics, the most common surgical option is a single-bundle anatomic reconstruction. Several studies have proven its success with comparable clinical outcomes between single-bundle and double-bundle techniques.[10–13,19,20] The concept of the I.D.E.A.L femoral tunnel placement was first proposed by Pearle AD and coworkers in 2015 in an attempt to imitate the characteristics of native ACL more closely and achieve more preferable clinical outcomes.[17] We have modified the I.D.E.A.L technique by moving the location of the femoral tunnel more anteriorly to cross the anterior edge of the lateral intercondylar ridge (3-4 mm) with a favorable clinical outcome in a short-term follow-up.

Cadaveric dissections have revealed that, albeit the ACL femoral insertion site is oval in shape, the ligament fibers create a flat, ribbonlike structure 9 to 16 mm wide and 2 to 4 mm thick as it extends from the bone, resulting in a mismatch between the femoral footprint shape and the structure of the ligament. Making the tunnel in the center of the footprint or "covering the footprint" with the graft may not replicate the structure or efficacy of the native ACL.[17,21]

Histological studies have demonstrated that femoral ACL footprint consists of direct and indirect insertion sites; the direct insertion is composed of dense collagen fibers, located directly posterior to the resident's ridge, extending posteriorly but does not reach the posterior femoral articular cartilage, while the fibers of indirect insertion located posterior to the direct insertion, spans posteriorly and merges with the posterior articular cartilage of the femoral condyle.[15] Fibers of the direct insertion create a strong and secure osseous attachment that allows transmission of the majority of the mechanical load to the joint, whereas indirect insertion fibers have a minimal stabilizing role in restricting tibial translation and rotations; this means that it is reasonable to establish the tunnel in the direct insertion

Table 1: Shows the socio-demographic data of patients.

Variables		Frequency	Percent %
Age	Less than 20 years old	7	5.8
	20-29 years old	54	45.0
	30-39 years old	53	44.2
	40 years old and more	6	5.0
Gender	Male	115	95.83
	Female	5	4.16
Affected side	Right	70	58.3
	Left	50	41.7
Duration	Less than 4 months	18	15.0
	4-7 months	33	27.5
	8 months-1 years	42	35.0
	More than 1 year	27	22.5
Activity level	Recreational athlete	76	63.4
	Competitive athlete	22	18.3
	Laborer	16	13.3
	Others	6	5.0
Mechanism of injury	Sport-related injury	98	81.7
	Fall from height	9	7.5
	Road traffic accident	13	10.8
	Others	0	0.0
Total		120	100%

Table 2: Summary of descriptive statistics of the scores

Scores	Items	Mean	S.D	Minimum	Maximum
IKDC	Preoperative	50.9625	4.86897	40.22	60.91
	Postoperative	83.8103	5.22965	72.41	95.40
Lysholm	Preoperative	51.1750	5.15420	40.00	67.00
	Postoperative	86.1917	5.29515	75.00	95.00
Tegner	Preinjury	7.5917	1.17033	5.00	10.00
	Preoperative	3.6333	.70928	2.00	5.00
	Postoperative	7.1833	1.21602	5.00	10.00

Table 3: Comparing mean between scores (preoperative & postoperative)

Scores	Items	Mean	N	S.D	T-test	P-value	Results
IKDC	preoperative	50.9625	120	4.86897	-64.097	0.000	Significant
	postoperative	83.8103	120	5.22965			
Lysholm	preoperative	51.1750	120	5.15420	-64.583	0.000	Significant
	postoperative	86.1917	120	5.29515			
Tegner	Preinjury	7.5917	120	1.17033	509.107 *	0.000	Significant
	preoperative	3.6333	120	.70928			
	postoperative	7.1833	120	1.21602			

Note: * One Way ANOVA (F-Test)

Table 4: Distribution of the scores (IKDC and Lysholm) (preoperative and postoperative)

Variables	Range	items	Preoperative		Postoperative		Significant Test
			Frequency	%	Frequency	%	
IKDC	< 70	Poor	120	100	0	0.0	240.00 P=0.000
	70 – 79	Fair	0	0.0	25	20.8	
	80 – 89	Good	0	0.0	79	65.8	
	≥ 90	Excellent	0	0.0	16	13.3	
Lysholm	< 65	Unsatisfactory	119	99.2	0	0.0	236.129 P=0.000
	65 – 83	Fair	1	0.8	30	25.0	
	84 – 90	Good	0	0.0	73	60.8	
	91 – 100	Excellent	0	0.0	17	14.2	

region; over the anterior edge of the footprint instead of being in the center.[17,22]

Native ACL is a nearly isometric structure that exhibits a minimal change in length throughout knee range of motion. Isometric behavior of the graft is primarily determined by the femoral tunnel positioning; establishing the femoral tunnel in a nonisometric location may lead to increased anterior knee laxity and graft failure. The most isometric region, which is the typical site for femoral tunnel placement, is a relatively narrow bandlike area proximal and anterior along the resident's ridge. From the biomechanical point of view, placing the graft in this location can also serve a more convenient time-zero stability and a lower tension-flexion pattern when compared with a central tunnel position.[17,23,24]

However, women have more ligamentous laxity and are more prone to sustain ACL rupture; our study showed that 95.83% of the patients were males, this male predominance also demonstrated by other studies such as Razi et al.[25] (91.6% male), Sajjadi et al.[26] (86.6% male), and Cury et al.[27] (96.7% male), which may be related to a higher rate of male participation in sports activities. Most of the patients were young aged-athletes between 20-39 years old (89.2%); this demographic finding is supported by many other studies,[25,26,28] as younger people are more likely to be engaged in strenuous activities than older people.

Right side injury was more common (58.3%) as compared to the left side; this finding is compatible with a study performed by Brophy et al., which showed that the dominant kicking leg was injured more commonly than the supporting side.[29] Also consistent with a study performed by Cury et al.,[27] in which 70% of participants had right side injuries. Though ACL rupture can be caused by various types of activities, the primary mechanism of injury in our study was sports activities, particularly football, which comprises 81.7% of cases; this finding is consistent with other studies such as Razi et al.,[25] and Gianotti et al.,[1] Everhart et al.[28]

The mean preoperative and 1-year postoperative Lysholm score was 51.17 and 86.19, respectively with (p-value of 0.000); it could be noticed that there was considerable improvement in the mean Lysholm score after ACL reconstruction in all patients; this is consistent with a study performed by Thapa et al.,[20] that showed a mean preoperative and 6 months postoperative Lysholm scores of 48.48 and 91.58, respectively. A similar study performed by Colombet et al.[30] showed a mean Lysholm score of 75.6 preoperative and 90.8 postoperatively. Yasen et al.[31] in their study demonstrated that the mean Lysholm score was 54.9 before the operation and 88.1 postoperatively. 25% of our cases rated fair, 60.8% of cases were rated good, and 14.2% were rated excellent functional outcomes after 1-year follow up, similar to a study conducted by Jonathan et al.[32] that scored 90% of patients as good or excellent at 24 months of follow-up. Another study performed by Kilinc et al.[33] showed that 57.1% of cases were excellent, 39.3% were good, and 3.6% were fair level.

We found that the mean IKDC score was 50.96 (40.22 to 60.91) and 83.81 (72.41 to 95.40) preoperative and postoperative, respectively, with a (P-value of 0.000), similar to a study performed by Colombet et al.,[30] which showed that the mean preoperative IKDC score was 60.4±15, and 87.6±10.6 postoperatively. In a similar study performed by Hussein et al.,[31] the mean preoperative IKDC score was 67.7 and 91.8 postoperative, with an average follow-up of 51.15 months.

Concerning the Tegner score, values were 7.5917, 3.6333, and 7.1833 preinjury, preoperative and postoperative, respectively, with a (p-value of 0.000), which shows a statistically significant improvement in the functional status of patients and their ability to return to preinjury activity level and sport participation, this finding is comparative with outcomes of a study conducted by Chen K. et al.[12] which showed that the mean Tegner score was 2.47 and 6.59, preoperative and postoperative, respectively. In a similar study by Schurz M. et al.,[34] the mean preoperative Tegner score was 2, and postoperative follow-up showed the mean score of 6.

5. Conclusion

Anatomical single-bundle ACL reconstruction with our modified I.D.E.A.L technique of femoral tunnel placement showed promising short-term results in terms of; improvement of the functional outcome and reestablishment of the native knee kinematics.

6. Source of Funding

None.

7. Conflict of Interest

The authors declare no conflict of interest.

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Cite this article: Rasul BM, Fatah RMN. Short-term functional outcomes of anatomic single-bundle ACL reconstruction using modified I.D.E.A.L technique. *Indian J Orthop Surg* 2022;8(2):101-107.