Interference screw-dependent internal bracing for anterior cruciate ligament reconstruction: a comparative study

Ehab R. Badawy[a], Ali H. Ismaeil[b], Alaa A. Abououf[c], Osama S. Gaarour[a]

[a]Department of Orthopedic Surgery, Mansoura University, Mansoura, [b]Department of Orthopedic Surgery, Rashid Hospital, Dubai, UAE, [c]Department of Orthopedic Surgery, Aswan University, Aswan, Egypt

Correspondence to Osama S. Gaarour, MD, Algomhoria Street, Mansoura University, Mansoura 33516, Egypt
Tel.: +0502948011; fax: +20 50 239 733/+20 50 239 7900; e-mail: osama_samir@mans.edu.eg

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Background
The internal brace augmentation technique was introduced to protect the graft till the completion of the ligamentization process. This was achieved by adding a synthetic implant to the anterior cruciate ligament (ACL) graft. However, the rarity of reports comparing this principle to the traditional ACL reconstruction represents an obstacle to reaching a consensus about the effectiveness of this technique. Herein, we compared a simple economic modification of the internal brace augmentation technique during the ACL reconstruction with the traditional ACL reconstruction.
Patients and Methods
The study included skeletally mature patients diagnosed with ACL tears who underwent reconstruction surgery between January 2022 and January 2023 (46 patients were included). They were allocated into two groups: the case group, the internal brace group (IB), which included 21 patients, and the control group, the graft only group (GO), which included 25 patients. The patients were followed up for at least 1 year regarding the time of return to the previous level of activity, the International Knee Documentation Committee Subjective Knee Evaluation score at 1 year, the Lachman test, the pivot shift test, and the associated complication rate.
Results
Although both groups scored an excellent International Knee Documentation Committee Subjective Knee Evaluation score (>80), there was a higher statistically significant improvement in the IB group with a mean and SD of 94.8 ± 1.9 compared to the GO group with a mean and SD of 90.6 ± 2.54. Regarding the return to the preinjury activity level, the IB group showed statistically significant earlier return compared with the GO group with a mean and SD of 9 ± 1.6 months compared to 11.8 ± 1.5 months. Furthermore, the IB group showed a statistically significant superior improvement in the anteroposterior knee stability evaluated by the Lachman test.
Conclusion
The interference screw-dependent internal bracing for ACL reconstruction has shown better short-term patient-reported outcome measurements, faster return to preinjury level, and better objective anteroposterior knee stability at 1 year when compared to the traditional technique with adding no extra cost at all.

Keywords:
anterior cruciate ligament, internal brace, ligamentization

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Background

Currently, anterior cruciate ligament (ACL) reconstruction is considered one of the most prevalent surgeries in the field of orthopedic surgery. Graft failure represents one of the major complications of such surgery. Many factors can cause graft failure, including trauma, technical error, and biological failure [1–3]. Graft maturation plays an important role in protecting against early failure. As a result, protecting the graft until its full maturation is of profound importance [4].

For the graft to mature, it passes through three phases: the early healing phase, the proliferative phase, and the maturation phase [5,6]. The tensile strength of the graft decreases gradually during the early healing phase, reaching its lowest during the proliferative phase. Afterward the graft gradually regain its strength through the maturation phase [7,8]. The time frame for early healing and proliferative phases reaches up to 12 months. Over this period, if the graft is subjected to a load greater than its low ultimate tensile strength, inevitable failure will occur [9–11].

Internal brace augmentation technique was introduced to protect the graft till the completion of the ligamentization process. This was achieved by adding a synthetic implant to the ACL graft [12,13]. This

technique has been proven beneficial in tACL repair [13,14] along with other ligament repairs like modified Broström and ulnar collateral ligament repair [15–17]. Furthermore, multiple cadaveric and clinical reports have proven its biomechanical properties to support the ACL graft during reconstruction surgeries. However, the rarity of reports comparing this principle to the traditional ACL reconstruction represents an obstacle to reaching a consensus about this technique.

Herein, we compared a simple economic modification of the internal brace augmentation technique during the ACL reconstruction with the traditional ACL reconstruction.

Patients and methods

The current case–control study was conducted at the authors' institute after approval of the ethical and scientific committee of the related medical school. The authors confirm that written informed consent has been obtained from the involved patients; and, they have given approval for this information to be published in this study. The study included skeletally mature patients diagnosed with ACL tears who underwent reconstruction in our Orthopedic Surgery Department between January 2022 and January 2023 (46 patients were included). The sample size was calculated using the online Biomath Calculator application. They were allocated into two groups: the case group, the internal brace group (IB), which included 21 patients, and the control group, the graft only group (GO), which included 25 patients. The exclusion criteria were partial tears, associated ligamentous knee injury requiring surgery, associated malalignment requiring correction, and revision surgeries.

Preoperatively, all patients underwent standard history taking, clinical assessment, and routine laboratory and imaging investigations. The diagnosis of ACL tear was confirmed based on the history, clinical examination, and the knee MRI findings.

The main preoperative variables collected were age, sex, BMI, the associated knee injuries, the time lapse before the surgery (in weeks) and the preoperative International Knee Documentation Committee Subjective Knee Evaluation (IKDC) score.

All patients underwent ACL reconstruction by two senior consultants specialized in arthroscopic surgery. We harvested the graciles and semitendinosus tendons and classically prepared them into a quadrable hamstring tendon graft. An ACL TightRope II Implant from Arthrex was placed on the femoral side while the tibial side was secured with Ethibond sutures No 2. Graft tensioning was performed at 70 N for 15 min, measured by a validated tensiometer. Both the diameter and the length of the graft were measured before implantation. The femoral tunnel was drilled through the anteromedial portal followed by drilling of the tibial tunnel. A No. 2 Vicryl loop was passed from the femoral to the tibial tunnel to drive the adjustable loop from the tibial to the femoral side.

For the GO group, the femoral fixation was classically done via ACL TightRope II implant, whereas the tibial fixation was done via interference screw.

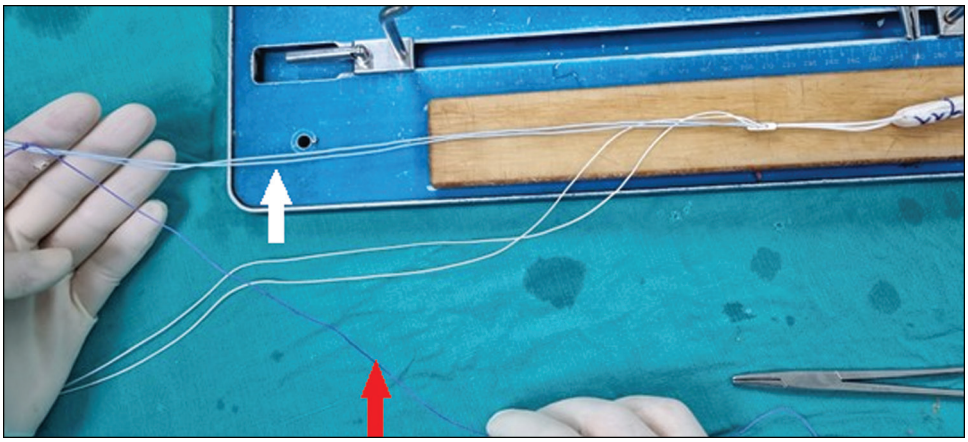
For the IB group, we used the strings of the ACL TightRope II implant as the internal brace device by reflecting them from the femoral side through the femoral tunnel into the tibial tunnel. We attached the two free ends of the flipping strings (FiberWire) to a No. 2 Vicryl string, keeping this attachment away from the button (Fig. 1). Afterward the adjustable loop with the attached Vicryl string was passed from the tibial to the femoral side. Then, the graft was pulled till the button passed outside the femoral cortex, which was confirmed by flipping. At this point, we had the tibial end of the graft and the Vicryl string fixed to the free ends of the loop emerging from the tibial side. Subsequently, the latter was pulled down, bringing back these threads through the femoral and the tibial tunnels emerging outside the skin at the tibial side. Finally, the zipping threads of the adjustable loop were pulled alternately to introduce the graft into the femoral tunnel.

At this point, we had both (a) the sutures attached to the tibial side of the graft and (b) the two threads of the internal brace emerging outside the tibial tunnel. Knowing that each of them needed to be fixed in different tension, we innovated our technique to use the interference screw to act as a single fixation device with two different tensions.

Instead of using the guide wire to direct the screw, one of two threads of the internal brace was passed through the screw and through the screwdriver by a wire passer to appear from the handle side of the screwdriver (Fig. 2).

Afterward the screw was introduced into the tibial tunnel along this string by placing some tension on this thread while the knee was flexed (Fig. 2). Meanwhile, a posterior drawer force was applied to the knee. Subsequently, the knee was fully extended, and the two threads of the internal brace (one inside the screw and the other outside the screw) were tied over the interference screw head using a knot pusher (Fig. 3). This full extension position was planned to avoid flexion deformity postoperatively.

Figure 1:



The two free ends of the flipping threads (white arrow) were attached to a No. 2 Vicryl thread (red arrow), and we considered keeping this attachment away from the button.

Figure 2:

One of two threads of the internal brace was passed through the screw and through the screwdriver by a wire passer to appear from the handle side of the screwdriver.

An arthroscopic examination was done to ensure the internal brace was lax in flexion and tight in extension. The position of the internal brace is better to be in front or on either side of the graft to allow for better visualization (Fig. 4).

Postoperative range of motion was encouraged, and weight-bearing was allowed as tolerated. A hinged knee brace with full range was used to protect the graft for 1 month. Full weight bearing was allowed after 1 weeks. Physiotherapy was encouraged as soon as possible.

The patients were followed up for at least 1 year regarding the timing of return to the previous activity level and the IKDC score. Furthermore, the Lachman test, the pivot shift test and the associated complication rate were recorded.

The study's primary outcomes were the differences in the IKDC score and the difference in the timing of return to the previous activity level between both groups. The secondary outcomes were the differences in the Lachman and pivot shift tests between both groups.

The collected data were tabulated and analyzed via the SPSS software (IBM SPSS Statistics for Windows, Version 22.0. IBM Corp., Armonk, NY, USA). Categorical data were expressed as numbers and percentages, whereas numerical data were expressed as mean (with SD) and median (with range and interquartile range). Afterward the appropriate statistical tests were used accordingly. A *P* value less than 0.05 was considered significant.

Results

Both groups were matched regarding age, BMI, the associated knee injuries, and the time lapse before the surgery given that the differences between the central tendencies and the variances were statistically insignificant (Tables 1, 2). In the IB group, the mean age, BMI, time to surgery, and preoperative IKDC score were 24.95 ± 4.2 years, 25.5 ± 1.8 kg/m^2, 5.38 ± 2.5 weeks, and 65.02 ± 3.78, respectively. In the GO group, the mean age, BMI, time to surgery, and preoperative IKDC score were 24.92 ± 4.1 years, 25.7 ± 2.2 kg/m^2, 6.04 ± 2.79 weeks, and 62.824 ± 3.28, respectively.

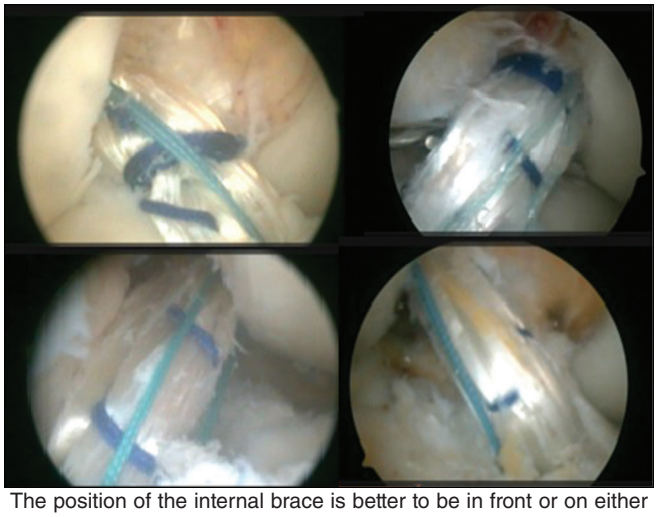
Regarding the success rate, there was no statistical difference between both groups, with a success rate of 95% for the IB group and 96% for the GO group, with only one failed case in each group. No infection was reported in either group, with only one case of arthrofibrosis in the IB group, which needed only manipulation under anesthesia.

Regarding the postoperative objective evaluation of the patients, the IB group showed a statistically significant superior improvement in the anteroposterior knee stability evaluated by the Lachman test. On the other

Figure 3:

The internal brace (one inside the screw and the other outside the screw) were tied over the interference screw head using a knot pusher.

Figure 4:



The position of the internal brace is better to be in front or on either side of the graft to allow better visualization of the internal brace.

hand, there was no significant difference between both groups regarding the rotational knee stability evaluated by the pivot shift test (Table 3).

Regarding the patient-reported outcome measurements (PROM), both groups reported excellent short-term outcomes regarding the IKDC score (>80). However, there was a higher statistically significant improvement in the IB group, with a mean and SD of 94.8 ± 1.9 compared to the GO group with a mean and SD of 90.6 ± 2.54 (Table 4).

Regarding the return to the preinjury activity level, the IB group showed statistically significant earlier return compared with the GO group with a mean and SD of 9 ± 1.6 months compared to 11.8 ± 1.5 months (Table 4).

Discussion

Although both techniques showed excellent PROM, our technique of internal bracing to augment the ACL reconstruction has shown a slight statistically significant superiority over the traditional ACL reconstruction with the value of adding no extra cost of another implant. Moreover, it showed a statistically significant faster return to the preinjury level than the traditional reconstruction.

Objectively, our technique showed a statistically significant superior anteroposterior stability of the knee joint compared to the traditional reconstruction when evaluated by the Lachman test.

Using the internal brace with ACL reconstruction provides added protection for the graft during the remodeling phases, during which there is collagen and extracellular matrix breakdown [18]. The material used for internal bracing should be biocompatible, nonreactive, economical, and strong enough to withstand the forces applied to the knee joint [19].

The advantages of internal bracing include providing an independent tension from the graft, protecting the graft during the healing process, and allowing earlier rehabilitation. However, the disadvantages include the

Table 1: The data collected preoperatively from both groups

Groups	Age	BMI	Time to surgery (weeks)	IKDC pre
IB group				
Number	21			
Mean±SD	24.95 ± 4.2	25.5 ± 1.8	5.38 ± 2.5	65.02 ± 3.78
GO group				
Number	25			
Mean±SD	24.92 ± 4.1	25.7 ± 2.2	6.04 ± 2.79	62.824 ± 3.28
P value	0.851	0.724	0.456	0.07

IKDC, International Knee Documentation Committee Subjective Knee Evaluation.

Table 2: The associated intra-articular lesions with each group

	Groups		Total	χ^2 asymptomatic significance (2-sided)
	IB group	GO group		
Associated lesions				
None	10	13	23	0.886
LM repair	4	4	8	
MM repair	2	2	4	
LM PM	2	2	4	
MM PM	2	4	6	
MCL	1	0	1	
Total	21	25	46	

Table 3: Comparison between both groups regarding the Lachman and pivot shift tests

	Groups		Total	χ^2 asymptomatic significance (2-sided)
	IB	GO		
Lachman G				
Negative	17	10	27	0.032
G1	3	13	16	
G2	0	1	1	
G3 (failed)	1	1	2	
Total	21	25	46	
Median (interquartile range)	0	1 (1)		
Pivot shift test				
Negative	17	21	36	0.0876
G1	3	3	8	
G2	0	0	0	
G3 (failed)	1	1	2	
Total	21	25	46	
Median (interquartile range)	0	0	0	

Table 4: Comparison between both groups regarding the International Knee Documentation Committee Subjective Knee Evaluation score and time to return to previous level of activity

Groups	IKDC 1 year	Return to activity (months)	Mann–Whitney test
IB group			
N			
Valid	21	21	<0.001
Missing	0	0	
Mean±SD	94.8 ± 1.9	9 ± 1.6	
Median (IQR)	95.4 (94.3–96.6)	9 (8–10)	
GO group			
N			
Valid	25	25	<0.001
Missing	0	0	
Mean±SD	90.6 ± 2.54	11.8 ± 1.5	
Median (IQR)	90.8 (88.7–91.4)	12 (11–13)	

IKDC, International Knee Documentation Committee Subjective Knee Evaluation.

potentiality for joint over-constraining, as well as stress shielding of the graft [20].

We fix the graft and the internal brace in two different knee positions to avoid joint over-constraining. The former is fixed during knee flexion, while the latter is fixed with the knee semi-extended, thus preventing over-stretching of the graft. Moreover, the graft itself experiences some sort of extra loading that stimulates the ligamentization process.

The internal brace augmentation of ACL reconstruction has proved to have superior stability in many biomechanical studies. Noonan *et al.* [21] concluded that the independent reinforcement of soft-tissue grafts with suture tape strengthened the performance of the grafts with tibial screw fixation by significantly improving dynamic elongation at increased stiffness and ultimate strength.

Many clinical publications were reported about the internal brace augmentation of the ACL reconstruction,

and, only two reports had compared their techniques to the conventional ACL reconstruction [22,23]. It is worth noting that both of them had used an extra implant for the fixation of the internal brace on the tibial side, which was added to the cost of surgery.

Matching with our hypothesis, in 2019, Bodendorfer *et al.* [22] concluded that the internal brace augmentation of ACL reconstruction was associated with improved patient-reported outcomes, less pain, and earlier return to preinjury activity level when compared with standard hamstring ACL reconstruction. However, he used a knotless anchor to fix the internal brace at the tibial side. This makes our technique more economical by reducing the cost of the surgery.

In 2021, Parkes *et al.* [23] concluded similar patient-reported outcomes, function, and return to sport between groups at a minimum 2-year follow-up. He compared 36 patients utilizing the internal brace augmentation technique to 72 patients utilizing the traditional technique. The difference in the results may be attributed to the large variation in the sample size between both groups in his study.

Two pitfalls should be avoided; the first one is tightening the graft and the brace at the same flexion angle as the knee. This will have a deleterious effect on the range of motion. The second pitfall is the possibility of having a screw divergence. To overcome this, it is advised to put some tension on the string to act as the guide wire.

This study had some limitations; the anteroposterior knee stability was better quantified by the KT-1000 arthrometer. However, due to its unavailability, we used the Lachman test. Furthermore, longer-term studies should be conducted to report this technique's long-term outcome including the failure rate.

In conclusion, the interference screw-dependent internal bracing for ACL reconstruction has shown better short-term PROM, faster return to preinjury level, and better objective anteroposterior knee stability at 1 year when compared to the traditional technique with adding no extra cost at all.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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