Original Article

Miniplate Suture Button Augmentation for Soft Tissue Graft Tibial Fixation in Anterior Cruciate Ligament Reconstruction

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Background: Anterior cruciate ligament (ACL) reconstruction requires reliable and rigid graft fixation. Tibial-sided fixation is frequently cited as the "weak point" of the femur-graft-tibia construct. Some authors have recommended supplemental fixation with a staple or screw suture to post improve the strength and stiffness of the fixation. However, with these fixations, there is a risk for symptomatic hardware. Miniplate is flatter than screw or staple and does not penetrate the bone when attached. It is used as a button for suspensory fixation to enhance interference screw tibial fixation.

Objective: To evaluate the clinical outcomes of the miniplate suture button for supplemental soft tissue graft tibial fixation in ACL reconstruction.

Materials and Methods: A retrospective study was carried out between August 2016 and December 2019. A total of 40 patients had undergone primary ACL reconstruction, performed with hamstring tendon grafts that were secured using a miniplate suture button for supplemental interference screw tibial fixation. A total of 18 patients were excluded, leaving 22 patients at 1-year follow-up.

Results: At least 1-year follow-up, the remaining 22 patients had significant difference between preoperative and postoperative outcome of anterior drawer test, Lachman test and pivot shift test ($p<0.05$). Lysholm knee scores improved significantly from 54.0±12.53 to 90.04±5.38. However, 3 patients (13.6%) experienced symptomatic hardware pain and 3 patients (13.6%) tendered around the miniplate site. There were no radiographic changes in miniplate displacement, deformed or broken plate, and bony reaction around miniplate.

Conclusion: The use of a miniplate suture button as a supplemental fixation showed adequate fixation strength and showed good results in postoperative manual ligament laxity test and functional scores at minimum 1-year follow-up. However, there is still symptomatic pain at the hardware site.

Keywords: Anterior cruciate ligament reconstruction, Supplemental fixation, Suture button

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Anterior cruciate ligament (ACL) injuries account for 50% or more of all knee injuries[1]. They often require surgical reconstruction followed by extensive long-term rehabilitation[2]. ACL reconstruction has been a successful operation, with satisfactory outcomes in 75% to 97% of patients. However, a significant number of patients 10% to 15% will require a revision[3-5]. The cause of failures are traumatic (32%), technical (24%), biologic (7%), combination (37%), infection (<1%)[6].

Regarding surgical fixation, failure tibial-sided fixation has been implicated as a cause of both early failure and late anterior-posterior laxity[7,8]. Because of the lower bone mineral density of the proximal tibia compared with the distal femur and the angle at which the forces are applied to the graft on the tibial side[9].

Devices for ACL graft tibial fixation can be divided according to the location of fixation: Aperture (intra tunnel) and suspensory (extra tunnel) fixations, aperture fixation fixes the graft closer to the joint line, decreasing working length and thereby increasing the stiffness of the construct. However, this method relies on adequate metaphyseal bone stock for interference fixation[10]. Suspensory fixation theoretically provides more secure fixation via attachment to dense metaphyseal cortical bone but also increases working length, and permits sagittal and longitudinal micromotion, which may interfere with osseous integration of the graft[11,12].

When comparing 2 systems, graft constructs

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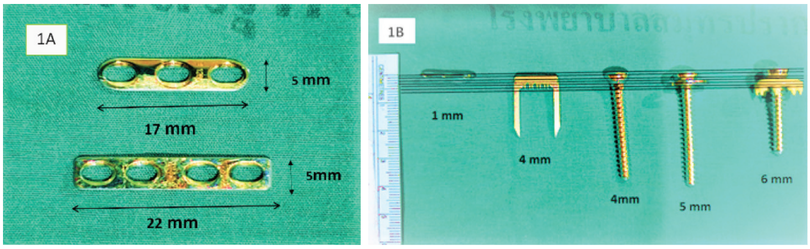

Figure 1. (A) Miniplate sizes: 17 mm length, 5 mm width (3 holes) and 22 mm length, 5 mm width (4 holes). (B) Compare implants thickness: miniplate has a minimum thickness of 1 mm, staple and 4.5 cortical screw head have 4 mm thick, screw plus metal washer have a thickness of 5 mm, while screw plus spiked washer has the maximum thickness of 6 mm.

fixed to tibial bone at the intra tunnel with interference screws have been shown to undergo less stretching and be stiffer than either suspensory-fixed grafts (tying sutures over buttons) or grafts fixed externally to the drilled tunnel (staple, screw suture to post)[13,14]. Persson et al[15] study of 38,666 patients from the Scandinavian knee ligament registries 2004 to 2011, the study showed the most common soft tissue graft tibial fixation was intra tunnel fixation (interference screw 48% and Intrafix 34%).

To decrease failure of tibial graft fixation, the combination of 2 systems (intra tunnel, extra tunnel) are applied to the graft on the tibial side. In most cases, the primary fixation is interference screw and supplement with extra tunnel fixation (staple, screw suture to post).

In 2016, Balazs et al[16] showed their systematic reviews 21 studies (15 biomechanical, 6 clinical), the results of this review argued that combined methods of tibial-sided graft fixation in ACL reconstruction result in strong initial fixation and less side-to-side laxity after healing, however, in clinical studies, the fixations had only interference screw combined with screw suture to post or staple that improved laxity measurements and clinical stability after surgery, but this improvement was at the cost of increased kneeling pain in staple group.

Almeida et al[17] reported 25% pain complaint rate at the screw site from the screw and metal washer to post method used for tibial fixation in ACL reconstruction. It was necessary to remove the tibial fixation screw and washer (10.8%).

Walsh et al[18] showed soft tissue grafts fixed with a combination of interference screw and suture button were able to withstand higher initial failure and ultimate failure loads and were also stiffer than grafts fixed with either interference screw or suture button alone: A biomechanical study was done in a porcine model, but in clinical studies still have few studies.

Straight miniplate stainless steel 1.0 mm thick, 16×5 mm (3 holes), and 22×5 mm (4 holes) generally used in a fixation of Maxillofacial surgery. It was used as a button for suspensory fixation in the present study. It costs lower than commercial buttons (800 Thai Bath) and available in general operating rooms (Figure 1A).

The purpose of the present study was to evaluate miniplate that used to a device suture button suspensory fixation for supplemental soft tissue graft interference screw tibial fixation in ACL reconstruction in clinical study. The study hypothesis was that postoperative local hardware pain and knee scores of using a miniplate suture button would improve compared to using a screw suture to post or staple because it is flatter and not penetrating bone as staple or screw (Figure 1B).

Materials and Methods

Patients and data collection

The present study was a retrospective study conducted in the orthopedics department of Samutprakarn Hospital between August 2016 and December 2019. A total of 40 patients underwent primary arthroscopic anatomical single-bundle ACL reconstruction using hamstring tendons with endobutton fixation in the femoral side, interference screw in the tibial side, and miniplate suture button for supplemental graft fixation in tibial side. Patients were informed of the benefits of ACL reconstruction and consent was obtained before surgery. All operative procedures were performed by a single surgeon (Wachiratarapadorn S). A total of 18 patients were excluded because they had concomitant other ligament injuries that required additional surgery (n=2), postoperative time less than 1 year (n=9), loss to follow-up (n=6), and graft failure (n=1) at 4 months postoperatively, likely because he resumed to sport sooner than recommended, leaving a study 22 patients at 1-year follow-up. The details are summarized in Figure 2.

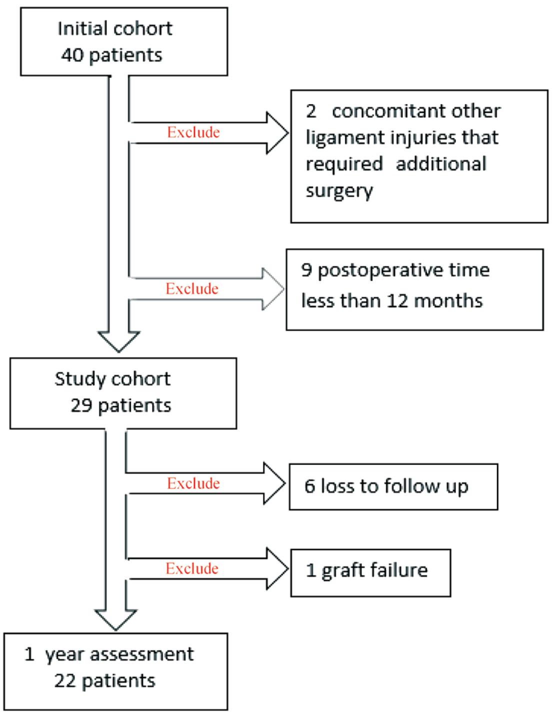

Figure 2. Flowchart of patients enrolled in the study.

The evaluation consisted of manual ligament laxity examination, Lysholm scores, clinical and radiographic assessment at local miniplate site. The present study protocol was reviewed and approved by the Ethics Committee of Samutprakarn Hospital (No. Sh02062).

Surgical techniques

All patients were operated on using the same surgical technique in the supine position, under general anesthesia or regional anesthesia with a pneumatic tourniquet at the base of the thigh (350 mmHg). Examination of the knee was performed to confirm the diagnosis and finding other ligaments laxity.

A 2.5 cm oblique incision was made above the pes anserinus medial to tibial tubercle. A semitendinosus tendon was harvested by the standard technique. The tendon were initially prepared as a typical 4-strand graft. If the graft measured less than 8.0 mm in diameter, the gracilis tendon was harvested and add to construct[19]. If the 4-strand semitendinosus graft was shorter than 6 cm in length, the graft was converted to 3-strand construct and gracilis tendon was added for increasing diameter (Figure 3A).

High anterolateral portal at the level of the inferior pole of the patella as close as possible to the lateral border of the patellar tendon and a low anteromedial portal was made under direct visualization using an 18-gauge spinal needle. It was about 1 to 1.5 cm from the medial border of the patellar tendon (not too medially as other accessory anteromedial portals that risk injury to the medial femoral condyle and shorter femoral tunnel)[20]. The femoral tunnel was drilled using a transportal technique, with the knee positioned in 90° flexion, the position of the tunnel was placed in the middle of the ACL femoral footprint that find out with ACL remnants, lateral intercondylar and bifurcate ridges and ACL template[21]. The femoral tunnel for endobutton fixation was prepared as usual technique. Place the knee at 70° to 90° of flexion. Director ACL Tip Aimer set at a 55° angle through the low anteromedial portal into the knee joint. Position the tip of the aimer, 2 to 3 mm anterior to the posterior margin of the anterior horn of the lateral meniscus, and slightly medial to mid-line of the ACL tibial attachment site. With proper placement of the tibial guide pin confirmed, use a fully fluted cannulated drill bit sized equal to the measured diameter of the ACL graft to drill the tibial tunnel. Graft passage from the tibial tunnel to femoral tunnel and fixed with ENDOBUTTON CL ULTRA (Smith & Nephew) fixation device for the femoral fixation. The graft tibial fixation was achieved with a cannulated biointerference screw, BIOSURE HA screw (Smith & Nephew) by the standard techniques.

After interference screw tibial fixation, the whipstitch suture tails of each strand were passed into each hole of miniplate. Manual tension of each strand and tied it (Figure 3B, C), 3-holes miniplate suture button was used in the case of 8 to 9 mm in diameter of tibial tunnel. If more than this, the author preferred to use 4-holes miniplate.

Rehabilitation protocol

All patients followed the same rehabilitation protocol. Postoperatively, the patient was placed in a hinged knee brace locked in full extension with immediate partial weight bearing on crutches. Continuous passive motion was started immediately from 0° to 45° of flexion and increased by 10° per day. The brace was unlocked at 2 weeks, and crutches were maintained until quadriceps control was reestablished, typically about 6 weeks. The brace was removed after 6 weeks.

Cycling and swimming after 8 weeks, and jogging after 3 months. Pivoting sports were allowed after 9 months.

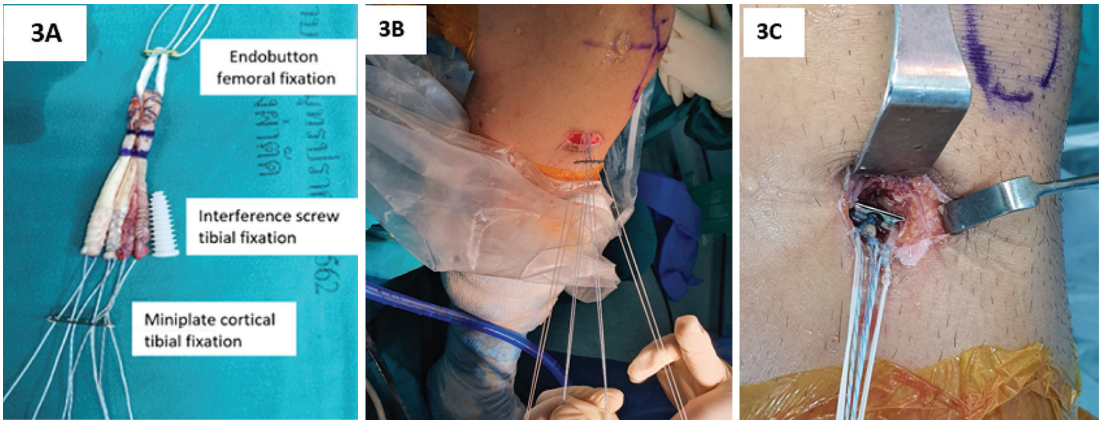

Figure 3. (A) The 6-strand graft (modified to 4 tails) of gracilis and semitendinosus tendons were prepared. Endobutton for the femoral fixation, Interference screw for the tibial tunnel fixation and supplement with Miniplate cortical tibial fixation were showed. (B) The whipstitch suture tails of each strand was pass into each hole of miniplate. (C) The tibial tensioning sutures were pulled until the button was seated outside the tibial tunnel and then multiple square knots were tied over Miniplate.

Statistical analysis

Data were analyzed using IBM SPSS Statistics, version 22 (IBM Corp., Armonk, NY, USA). Baseline characteristics, Clinical and Radiographic assessment were analyzed using descriptive statistics such as number, percentage, mean and standard deviation, minimum-maximum. A Wilcoxon signed rank test was used to compare preoperative and postoperative manual instability assessment while the Paired t-test was used to compare preoperative and postoperative Lysholm score. Significance was accepted for p-values less than 0.05.

Clinical evaluation

All patients were followed-up initially by the operating surgeon. All final clinical testing and evaluations were performed at a minimum of 1-year follow-up. Stability testing included anterior drawer test, Lachman test and pivot shift test.

Anterior ligamentous laxity was graded as Normal: no side-to-side difference. Grade I (mild): 3 to 5 mm more translation of the tibia on the femur, Grade II (moderate): 5 to 10 mm more translation of the tibia on the femur, Grade III (severe): >10 mm more translation of the tibia on the femur. The pivot shift test was graded as Normal: having no detectable shift, Grade I: slip, Grade II: definite movement, jump, or Grade III: transient lock. The clinical rating scales used the Lysholm Knee Score.The clinical assessments of the local miniplate site were evaluated about experienced of pain at site and tenderness of this site was test.

Radiographic evaluation

The present study reported radiographic of miniplate about displacement, deformed or broken plate and bony changes around the plate at the last follow-up.

Results

Assessment of demographic data

The baseline characteristics of the patients were shown in Table 1. Twenty-two patients were recruited. The mean age was 28.18±7.55 years (min-max 20.0 to 46.0). The majority of the patients were male (81.82.%). The main cause of ACL surgery was injury sustained playing sports (95.5%). Football injuries were the most common cause 68.18%, while Volleyball injuries were the second most common cause and all were women. The mean time from injury to surgery was 6.54±4.6 months (range 3.0 to 24.0). Patients were followed for a mean of 15.54±5.52 months (range 12.0 to 30.0), with a minimum of 12 months follow-up. Most patients did not have associate injuries (68.18%), combined with medial meniscus tear (13.64%), lateral meniscus tear (9.09%) and bicompartment (9.09%). ACL reconstruction was single procedure (68.18%), while meniscus repairs were combined 22.73% and partial meniscectomy 9.09%.

Anterior instability

In the preoperative anterior drawer test, 5 patients showed grade I, 13 patients showed grade II, and 3 patients showed grade III. There was only one patient had negative finding and when arthroscope, found

Table 1. Baseline characteristics of patients (n=22)

Characteristics	n (%)
Sex	
Male	18 (81.82)
Female	4 (18.18)
Age (years)	
Mean±SD	28.18±7.55
Min-max	20 to 46
Cause of injuries	
Sport	
• Football	15 (68.18)
• Volleyball	3 (13.64)
• Badminton	1 (4.55)
• Sepak Takarw	1 (4.55)
• Rugby Football	1 (4.55)
Falling down	1 (4.55)
Vehicle accident	0 (0.0)
Time between injury and operative (month)	
Mean±SD	6.54±4.6
Min-max	3 to 24
Follow-up time	
Mean±SD	15.54±5.52
Min-max	12 to 30
Associated injuries	
No	15 (68.18)
Medial meniscus	3 (13.64)
Lateral meniscus	2 (9.09)
Bicompartmental	2 (9.09)
Concomitant surgery	
No	15 (68.18)
Menicus repair	5 (22.73)
Partial menisectomy	2 (9.09)

SD=standard deviation

Table 2. Comparison of preoperative and postoperative manual laxity examination 1-year follow-up (n=22)

Examinations	Preoperative	Postoperative	p-value
Anterior drawer test (n=22)			<0.001*
Normal	1	11	
Grade I	5	9	
Grade II	13	2	
Grade III	3	0	
Lachman test (n=22)			<0.001*
Normal	1	10	
Grade I	3	10	
Grade II	14	2	
Grade III	4	0	
Pivot shift test (n=22)			<0.001*
Normal	5	15	
Grade I	10	6	
Grade II	6	1	
Grade III	1	0	

The p-value from Wilcoxon signed ranks test, * Significant at p<0.05

that there was bucket handle torn meniscus with locking.

In the postoperative anterior drawer test, 11 patients showed negative, 9 patients showed grade I, 2 patients showed grade II, and no patient showed grade III. There were significant differences between preoperative and postoperative anterior drawer test ($p<0.001$).

In the preoperative Lachman test, 3 patients showed grade I, 14 patients showed grade II, and 4 patients showed grade III. There was only one patient who was negative Lachman test and also negative anterior drawer test.

In the postoperative Lachman test, 10 patients showed negative, 10 patients showed grade I, 2 patients showed grade II, and no patient showed grade III.There were significant differences between preoperative and postoperative Lachman test ($p<0.001$) as shown in Table 2.

Pivot shift

In the preoperative pivot-shift test, 5 patients showed negative, 10 patients showed grade I, 6 patients showed grade II, and 1 patient showed grade III.

In the postoperative pivot-shift test, 15 patients showed negative, 6 patients showed grade I, 1 patient showed grade II, and no patient showed grade III. There were significant differences between preoperative and postoperative pivot-shift test ($p<0.001$) as shown in Table 2.

Functional score

Lysholm knee scores were improved significantly from 54.0±12.53 to 90.04±5.38 on preoperative and postoperative. There were significant differences between preoperative and postoperative Lysholm knee scores ($p<0.001$) as shown in Table 3.

Clinical assessment miniplate suture button location

There were 19 patients (86.36%) who had no history of local miniplate site pain. The pain was

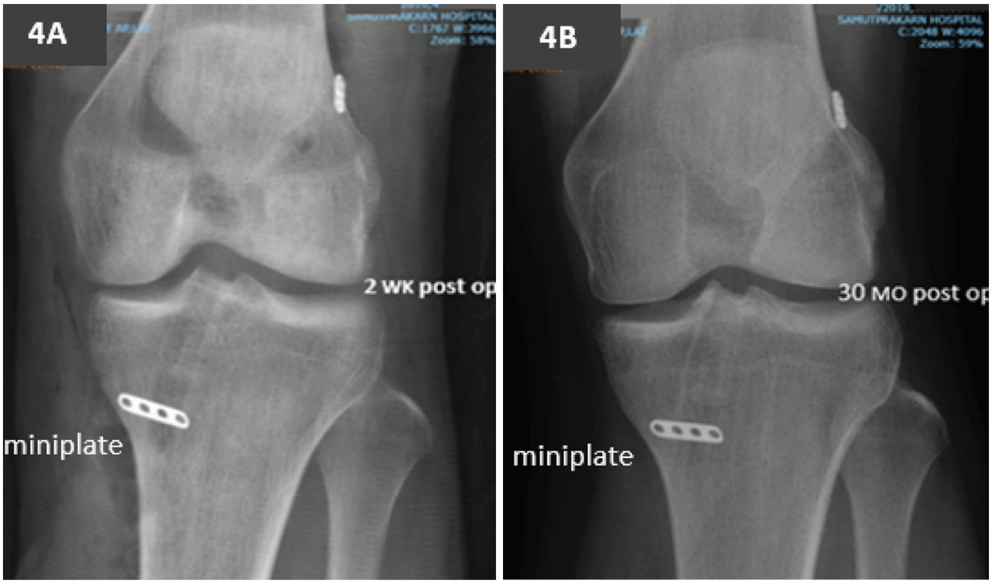

Figure 4. In the same patient: (A) 2 weeks postoperative plain film showed the location of miniplate on the proximal tibia. (B) 30 months postoperative plain film showed the same position of miniplate. There was not deformed or broken plate and bony change around this plate.

Table 3. Pre- and post-operative functional score assessment at 1-year follow-up (n=22)

	Lysholm score		p-value
	Preoperative	Postoperative	
Mean±SD	54±12.53	90.04±5.38	<0.001*
Min-max	25 to 81	79 to 100	

SD=standard deviation

The p-value from Paired t-test, * Significant at p<0.05

Table 4. Clinical assessment Miniplate suture button location at 1-year follow-up (n=22)

Characteristics	n (%)
Pain at miniplate location	
None	19 (86.36)
Inconstant and slight during severe exertion	3 (13.64)
Marked during severe exertion	0 (0.0)
Constant	0 (0.0)
Kneeling pain	2 (9.09)
Tender at location	
0=No tenderness	19 (86.36)
I=Tenderness to palpation without grimace or flinch	2 (9.09)
II=Tenderness with grimace and/or flinch to palpation	1 (4.54)
III=Tenderness with withdrawal (+ "Jump Sign")	0 (0.0)
IV=Withdrawal (+ "Jump Sign") to non-noxious stimuli	0 (0.0)
(i.e., superficial palpation, pin prick, gentle percussion)	

Table 5. Radiographic assessment miniplate suture button site at the last follow-up (n=22)

Follow-up time (months)	n (%)	Miniplate displacement	Deformed broken plate	Bony changes around plate
12 to 15	14 (63.64)	0	0	0
16 to 24	5 (22.72)	0	0	0
24 to 30	3 (13.64)	0	0	0

found in 3/22 patients (13.64%), it was inconstant and mild during severe exertion, and two of them had kneeling pain.

Tenderness at miniplate location was examined: 2/22 (9.09%) tendered to palpation without grimace or flinch, 1/22 (4.54%) tendered with grimace or flinch on palpation. In this group, two of them had history of local site pain, however, no patient wanted to remove the plate as shown in Table 4.

Radiographic assessment Miniplate suture button location

In the present study, showed the radiographic assessment of the last follow-up visit (range 12 to 30 months). There were no miniplate displacement, deformed or broken plate and bony changes around the plate (Table 5, Figure 4A, B).

One patient had computed tomography (CT) scan postoperative due to finding of endobutton breaking femoral cortex, however, in the study CT

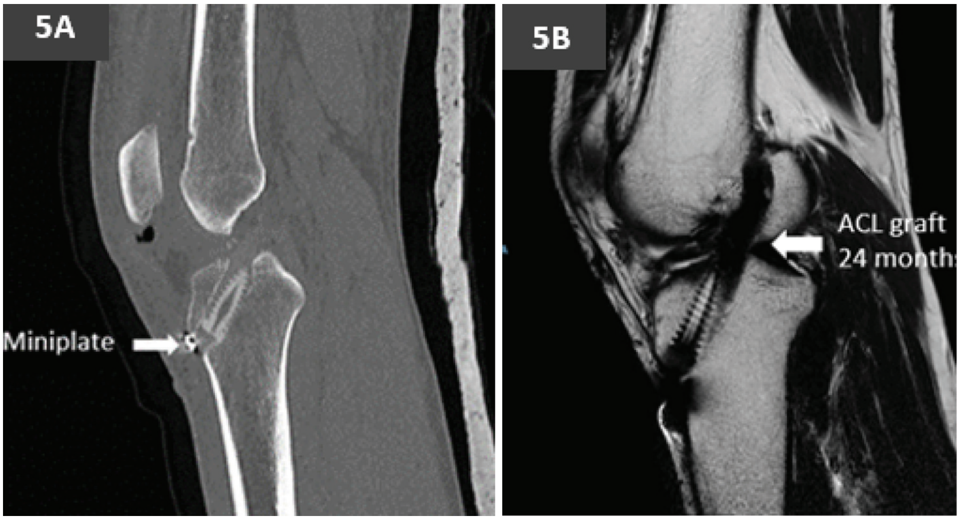

Figure 5. (A) CT scan film of the knee showed the location of miniplate and interference screw. (B) MRI film of the knee showed intact ACL graft after fixation with interference screw and miniplate supplemental fixation at postoperative 24 months.

scan (Figure 5A) showed the position of miniplate and interference screw. At 2 years post-operative, one patient presented with a locked knee, the magnetic resonance imaging (MRI) was done, which showed bucket-handle meniscus torn, however, ACL graft was intact as shown in Figure 5B.

Discussion

The tibial fixation is the initial weak of ACL reconstruction[7,8]. It is important to provide an adequate initial fixation to allow for aggressive rehabilitation before graft-bone integration occurs. Some authors have recommended supplemental fixation with a staple, screw suture to post for soft tissue interference screw fixation to improve strength and stiffness of the fixation. However, there is a risk for symptomatic hardware[16,17]. Miniplate suture button is flatter than staple and screw when combine with interference screw are able to withstand higher initial failure and ultimate failure loads and also stiffer than grafts fixed with either interference screw or suture button alone[18]. Therefore, the purpose of the present study was to identify clinical outcomes and radiographic evaluations after ACL reconstruction with hamstring tendon grafts, which used miniplate supplement interference screw tibial fixation at 1-year follow-up. The present study's findings confirmed the hypothesis that the manual ligament laxity examination and functional scores showed good results. However, the postoperative clinical evaluation of laxity was performed by the surgical team and prone to reporting bias. There were 3 patients (13.64%) complaint of pain at the site of the miniplate tibial fixation, the pain was inconstant and mild during severe exertion, and two of them had kneeling pain. The local site pain was confirmed with tenderness test, the results found positive in 3 patients (13.64%) and two of them had history of local site pain. Hill et al[22] showed a statistically significant reduction in clinical laxity as measured with the Lachman test, with the use of a supplementary tibial staple with a metal interference screw compared with interference screw group, although, in the combined group reported 28.6% had kneeling pain, while interference screw group found 7.4%. Teo et al[23] reported the use of a staple as a supplementary fixation in addition to the biointerference screw compared with only biointerference screw group, there were no difference in terms of objective arthrometer measurements and clinical outcomes. However, four patients (12.12%) from combined group experienced symptomatic hardware pain on kneeling, of which two patients had to remove the hardware. The details were summarized in Table 6.

The follow-up of 1 year is limitation of the study. The ideal follow-up should be 2 years or more, because at 1 year, most patients have not returned to play full sport. Rodeo et al(24) found substantial collagen bone connections between tendon and the tibial tunnel and that failure by tendon pullout from the tunnel occurred up to 8 weeks after surgery. By 12 weeks, there were no failures from tendon pullout at the tibial bone–tendon interface. In the present study, there was one patient graft failure at postoperative 4

Table 6. Outcomes of anterior cruciate ligament reconstruction using supplemental fixation in addition to the interference screw for tibial graft fixation in ACL reconstruction, using hamstring graft

Author	Year	Journal	Model femur	Model tibia	n	Follow-up (month)	Lysholm score	Pain (%)
The present study	2020	J Med Assoc Thai	Endobutton CL	BIS+miniplate	22	12	90.04±5.38	13.64 (no remove)
Teo, et al.[23]	2017	J Orthop Surg	Endobutton CL	BIS+staple	33	12	92.1±6.10	12.12 (6.06 remove)
			Endobutton CL	BIS	31	12	90.4±5.50	0.0
Hill, et al.[22]	2005	Am J Sports	TIS	TIS	27	24	81 to 100	7.4
			TIS	TIS+staple	21	24	86 to 100	28.6

BIS=biointerference screw; TIS=titanium interference screw

months, likely because he returned to sport sooner than recommend. Therefore, it can be concluded that the combined fixation interference screw and supplement with miniplate suture button on tibial side ACL reconstruction have adequate strength to allow for aggressive rehabilitation in early postoperative.

Conclusion

The use of a miniplate suture button as a supplemental fixation in addition to the biointerference screw for tibial hamstring graft fixation in ACL reconstruction showed adequate fixation strength to withstand the rigors of early aggressive rehabilitation at minimum 1-year follow-up and showed good results in postoperative manual laxity and functional scores and radiographic evaluation. However, there is still symptomatic pain and tenderness at the hardware site. This technique is simple, fast, and inexpensive, making use of the available instruments to enhance the security of graft fixation during ACL reconstruction.

What is already known on this topic?

Several studies have been published of the researches about supplemental ACL tibial graft fixation. Most of the devices for supplemental fixation are staple or screw suture to post. The results are good in clinical and biomechanical studies, however, the local site hardware pain are still the problem. The present study used miniplate suture button for supplemental ACL tibial graft fixation that still having few study.

What this study adds?

Miniplate suture button can use for supplemental ACL graft tibial fixation. The results are good in clinical score, manual ligament laxity test and radiographic evaluation. Although, it is flatter and dose not penetrate bone as other devices, it still has the local site pain. In the future, non-devices methods for supplemental ACL graft tibial fixation will be study to decrease local hardware pain.

Conflicts of interest

The authors declare no conflict of interest.

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