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Research Article

Double-Crossed Knotless Suture Anchor Repair of Quadriceps Tendon Rupture

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Abstract

Quadriceps tendon rupture is an uncommon injury but may result in long term disability if not adequately repaired. Many techniques are described for repair of acute quadriceps tendon rupture, including tendon-to-tendon repair, trans-osseous tunnels, synthetic augmentation, tendon plasty and the use of suture anchors. There is no single accepted surgical treatment. This study's objective was to assess the efficacy of a *double-crossed* suture anchor repair in the management of quadriceps tendon rupture.

Materials and methods

85 patient attended our institute for surgical management of quadriceps tendon rupture over eight years (2012-2019). Twenty patients were treated with the use of a *double-crossed* suture anchor fixation. These patients were allowed to weight bear in a hinged knee brace for six weeks following surgery. Eighteen out of twenty patients had one or more predisposing comorbidities, including obesity, diabetes, renal failure, quinolone and steroid use.

Results

Clinical and functional outcomes were recorded during follow up visits prospectively for a mean of one year (10-14 months). The mean knee flexion was 124 degree (120-130). All patients were able to return to activities of daily living (ADL) with a mean of 2

months (1.5-3 months) and return to work at a mean of 6 months (4-8 months). The mean Tegner, Cincinnati and Lysholm score at the latest follow up were 2.8 (0-5), 79.2 (60-88) and 90 (70-100), respectively. There were no early complications. There was no re-tear reported at the latest follow up.

Conclusion

The double-crossed suture anchor fixation is a safe and effective treatment option in managing quadriceps tendon ruptures.

Keywords: Quadriceps repair; Tendon rupture; Knotless technique; Suture anchor; Double-crossed suture

1. Introduction

Quadriceps tendon ruptures are uncommon but may result in long term disability if not adequately repaired [1-3]. Clayton and Court-Brown reported the incidence of distal quadriceps tendon avulsion as 1.37 cases per 100,000 per year with a mean age of 50.5 in men and 51.7 in women [4]. The aetiology of quadriceps tendon rupture includes reduced blood supply, repetitive microtrauma, diabetes mellitus, renal failure, steroid use [5-9,24] and previous knee surgery [9,14]. A direct blow injury or forceful eccentric quadriceps contraction may cause tendon rupture in younger patients; the force applied across the tendon exceeds its tensile strength causing it to tear. This commonly occurs in the mid-substance of the tendon or at the Musculo-tendonous junction [13,24]. Rupture may also occur spontaneously and bilateral simultaneous quadriceps tendon rupture has also been described. In these tears the aetiology is less certain. Spontaneous tendon rupture may be an end-state manifestation of a chronic degenerative process in the tendon tissue. Poor vascularity at the osseous tendon junction may result in local tissue hypoxia. Chronic medical conditions, chronic inflammation and certain medications can impair tendon healing, and the ability of the tenocytes to repair is overwhelmed, and tendon failure is inevitable [5-9,15]. A rupture in this situation usually occurs at the osseous tendon interface. In these cases, simple suture or end to end tendon repair is limited by the poor vascularity of this zone. Tendon ends are already pathological, and in conjunction with a poor host, optimal healing is difficult. Initial mechanical stability following primary suturing is compromised by a short distal stump and poor biomechanical strength of the suture configuration relative to the extensor mechanism's pull. Prolonged protection or immobilisation may result in quadriceps muscle atrophy and knee stiffness. Partial-thickness or small tears may resolve with conservative management. Full-thickness tears or high-grade partial tears often required operative repair [5,9]. Many surgical techniques described in the literature, including primary suturing of tendon ends, suture through patellar bone tunnels, repair augmentation with looped sutures proximally, autograft, allograft, suture or wires [13] · Maniscalco et al. were the first to describe the use of suture anchors for Achilles tendon repair, and their use has been expanded to quadriceps tendon repair [11,16]. The quadriceps muscle comprises the rectus femoris, vastus medialis, vastus lateralis, and vastus intermedius. The rectus femoris tendon widens distally to about 3-5 cm as it approaches the superior aspect of the patella. It continues over the superior aspect of the patella and becomes contiguous with the patellar tendon distally. The quadriceps tendon is a coalescence of the four muscles rather than four distinct layers. Quadriceps tears often extend medially and laterally through the patellar retinaculum, and these need to be included in the repair. The vastus

intermedius inserts directly on the patella and is separate from the rectus femoris more proximally [28]. Three vascular arcades, medial, lateral, and peripatellar, provide blood supply to the quadriceps tendon. A hypo-vascular zone exists about 1-2 cm superior to the patella [25]. Yepes et al. has divided the Quadriceps tendon according to the zones of rupture. Zone 1 is within 1cm of the patellar, Zone 2 is between 1 and 2 cm, and Zone 3 is above this [25]. It is Zone 1 injuries that are technically difficult to repair and have poor healing, and this provides the focus of our study. We endeavoured to develop a technique using a strong small diameter suture with minimal biological reaction. Using a low profile whip stitch through the quadriceps tendon maximises proximal strength and utilises suture anchors in the patella as distal fixation. Angled anchor placement with the double-crossing of the sutures may optimise pull out strength. Crossover of the sutures may enhance biological repair across the patellar footprint. Secure fixation would facilitate early mobilisation and enhanced recovery. This study's objectives were to assess a *double-crossed* suture anchor technique's effectiveness in quadriceps tendon repair of acute Zone 1 injuries.

2. Materials and Methods

85 patients attended our institution for quadriceps tendon repair over an eight year period (2012-2019). All patients underwent ultrasound scanning of the extensor mechanism. The mean age was 56 with a range of 48 to 64 years. The male to female ratio was 8:1. Unilateral quadriceps tendon rupture was found in 98% of patients and mostly involved the non-dominant limb. The most common site of rupture was at the insertion of the tendon to the patella in Zone 1. Over 70 % of patients had co-morbidities, including diabetes mellitus, renal failure, obesity, gout, steroid and quinolone use. Over 60% of patients had a BMI of 28 or more. Twenty patients were included in the study. All patients had acute full-thickness tears in Zone 1 of the tendon. Exclusion criteria included Zone 2 or 3 tears and all partial tears. Previous knee surgery or arthroplasty, or a neuromuscular condition that may impact rehabilitation were also excluded. Post-operatively all patients participated in an accelerated rehabilitation protocol. The patients were followed up to one year post-operatively, and the follow-up visits were planned at 1,3,6 and 12 months. The patient demographics, clinical and radiological data and functional scores were collected at each follow-up visit up to one year.

2.1 Case series

Twenty patients with isolated distal quadriceps tendon rupture were treated using a double-crossed suture anchor technique. All of them were male, with a mean age of 57. Mode of injury was eccentric forceful contraction of the quadriceps during a fall. The delay between the injury and surgery was a mean of 8.71 days (1-21 days). The body mass index (BMI) was a mean of 28.5 (23-32). Eighteen out of twenty patients had one or more predisposing factors: obesity, diabetes, chronic renal failure, corticosteroids and quinolone use. All patients had Plain X-Rays and Ultrasonography to confirm the diagnosis.

2.2 Surgical technique

The patient is painted and draped in a standard fashion with Chlorhexidine 2% and an Ioban 3M drape is used. A tourniquet is applied but not inflated. An 8 cm midline incision is made over the superior patella and quadriceps tendon with a size 22 blade. The haematoma is evacuated, and the tendon edge is freed up. Care is taken to identify the medial and lateral extension of the tear. A Krackow suture is placed into the lateral edge of the quadriceps tendon from distal to

proximal with a single limb of a 2 Fibre wire (Arthrex) for a distance of 6 cm. The suture is then brought out distally through the tendon to finish in the midline. This is then repeated on the medial aspect of the tendon. One end of each suture is crossed over to the other side and clipped in place (**Figure 1).** The patella's superior edge is prepared, and two 2.4mm guide pins are drilled into the proximal patellar corners at an angle of 45 degrees to the midline to a depth of 25mm (**Figure 2).** The two guide pins are over drilled with a 4.5mm cannulated reamer to a depth of 25mm. The free ends of the Krackow sutures on each side are crossed over and passed through the eyelet of a 4.75mm SwiveLock and the suture/anchor is pushed into a drill hole until the eyelet is fully seated.

(Arthrex). Each side of the repair, medial and lateral has one suture tail in each of the two anchors.

Therefore, even if one anchor fails, the remaining anchor still retains the fixation of both sides.

The repair is tested for stability by knee flexion and the suture ends are trimmed (**Figure 3).**

The wound is closed in layers and the knee is immobilised in a hinged brace (Don Joy).

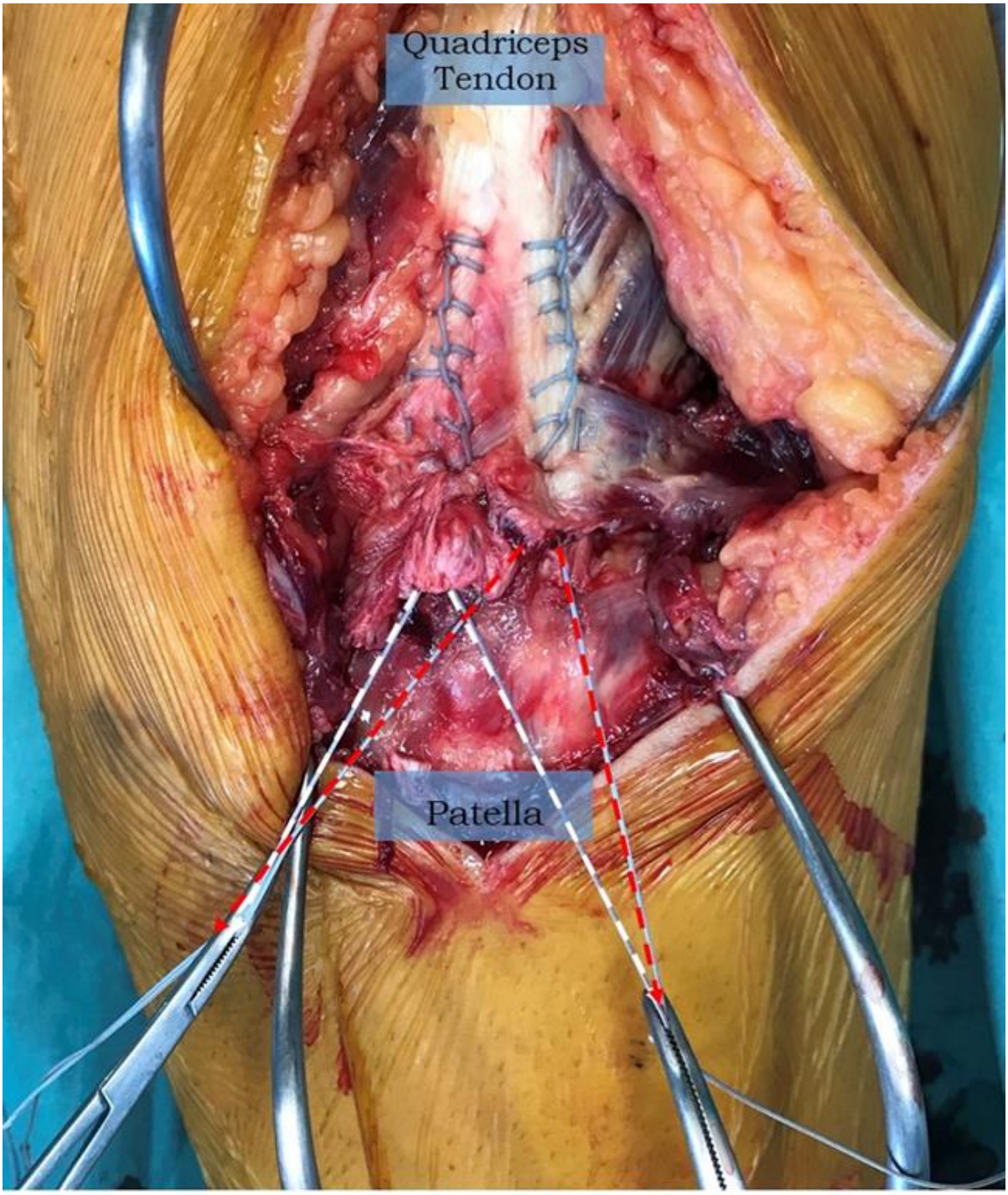

Figure 1: A Krackow suture (2 Fibrewire) has been passed up and then back down the medial aspect quadriceps tendon for 6 cm. The free ends are shown in white. This is repeated on the lateral side with another suture, the ends of which are shown in red. One suture end from each side is crossed over to join its twin.

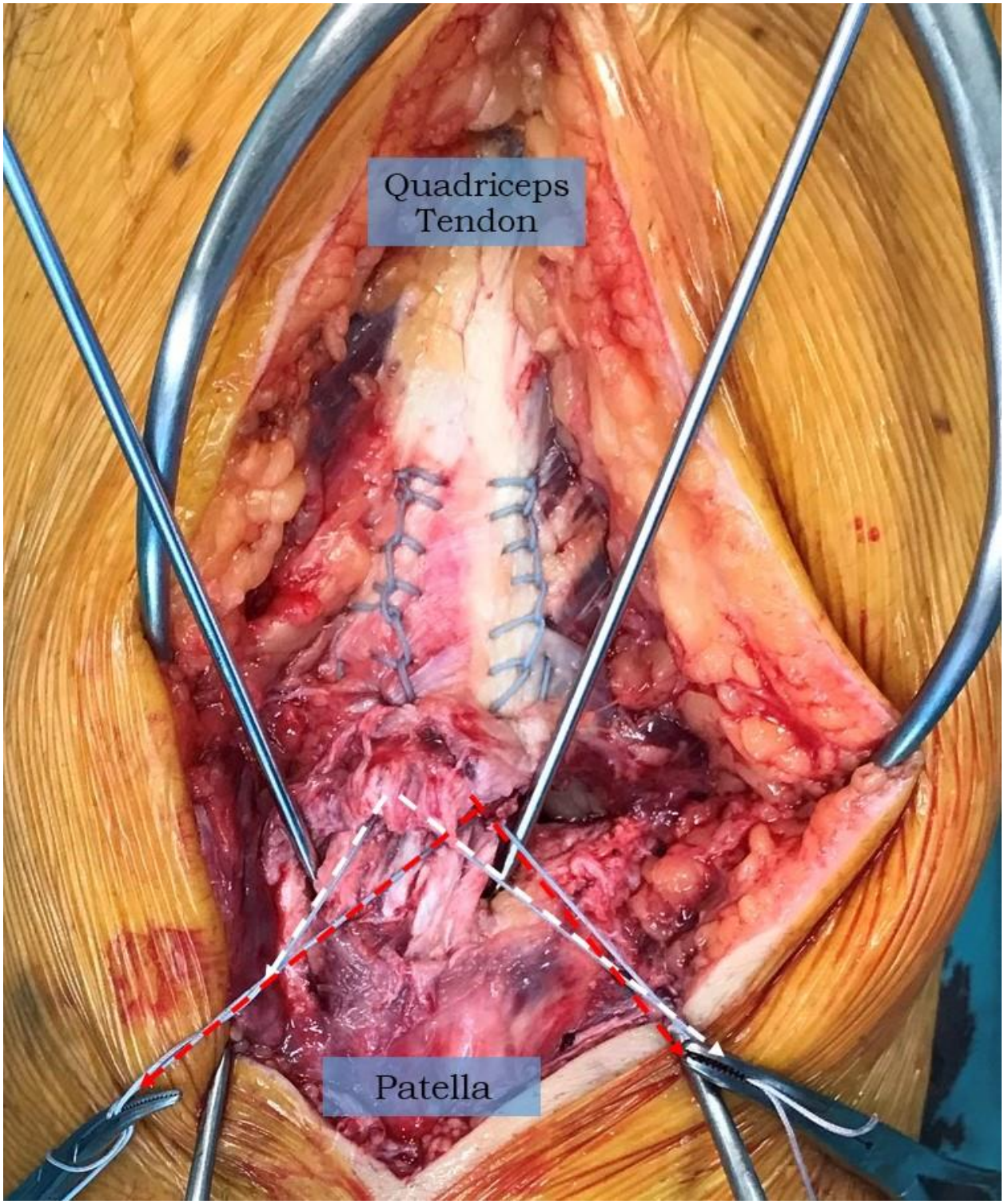

Figure 2: Two 2.4mm drill tip guides are placed on the superior aspect of the patella at a 45^0 angle to the coronal plane to a depth of 25mm. The two guide pins may then over drilled with a 4.5mm cannulated reamer to facilitate anchor fixation.

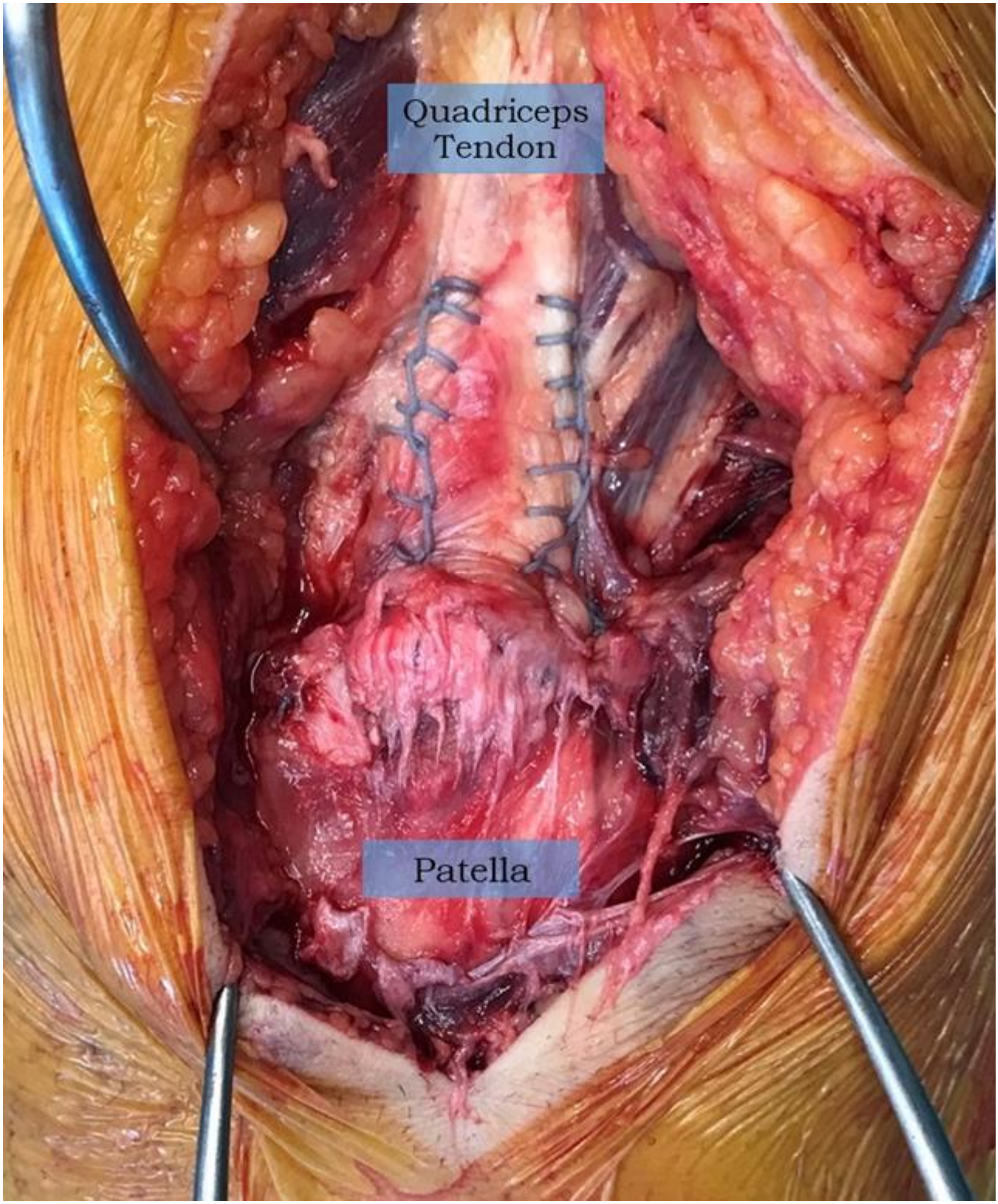

Figure 3: The completed repair with suture tails cut flush with the bone as part of knotless fixation. Each side of the repair, medial and lateral, has one suture tail in each of the two anchors. Therefore, even if one anchor fails, the remaining anchor still retains the fixation of both sides.

2.3 Rehabilitation protocol

Immediate protected weight-bearing was allowed post-operatively while using the splint. Isometric strengthening of the quadriceps started on the first post-operative day. Passive knee flexion $0\text{-}30^0$ in the first two weeks and then increased to $0\text{-}60^0$ in the next two weeks, and flexion range increased to 90^0 at six weeks. Partial to full weight-bearing was allowed at 8-10 weeks. Patients were allowed to return to work after three months and could participate in non-contact sports as desired. None of the patients played any contact sport.

2.4 Assessment method

The patient's overall subjective satisfaction, pain (VAS), knee range of motion and time to resume activities of daily living (ADL) were calculated at each follow-up visit. The Tegner [17], Cincinnati [18,19] and Lysholm scores were calculated.

3. Results

The mean operative time was 57 min (45-70 min). The average length of stay was three days. (2-3) There were no significant post-operative complications reported. The mean age was 56 (48-64), and they were all male. All twenty patients were followed prospectively for a mean of 12 months (10-14months). The mean active knee flexion was 124^0 (120-130). All patients were able to return to activities of daily living (ADL) with a mean of 2 months (1.5-3 months) and return to work at a mean of 06 months (4-8 months). **(Table 1).** The mean Tegner score at the latest follow up was 2.8 (0-5) versus 2.9 (0-5) before the rupture. The mean Cincinnati score was 79.2 (60-88) at the latest follow up versus 80.2 (62-90) before the rupture. The mean Lysholm score was 90 (70-100) at the latest follow up versus 95.2
(84-100) before the rupture. There was no re-tear reported at the latest follow up. **(Table 2)**

Enrolled Patients	20
Age (mean)	57.7
Gender	Male
BMI (kg/m^2)	28.5
Time to surgery	8.71 days (1-21 days)
Mean operative time	57 min
Average length of stay	3 days
Average Follow-up	12 months
Range of motion	124 (120-130)
ADL restarted	2 months (1.5-3 months)
Sports resumed	6 months (4-8months)

BMI: Body mass index

Table 1: Summary of patient characteristics

Scores	Before injury	Latest follow-up
Tegner	2.9 (0-5)	2.8 (0-5)
Cincinnati	80.2 (62-90)	79.2 (60-88)
Lysholm	95.2 (84-100)	90 (70-100)

Table 2: Functional scores before the injury and last follow-up

4. Discussion

Quadriceps tendon rupture has an incidence of 1.37% per 100,000 per year [4], but there has been an increase in quadriceps tendon rupture treated surgically. The Finnish National Hospital discharge register reports the incidence of quadriceps tendon rupture increased by 411% from 0.55 to 2.82 per 100,000 people/year from 1997 to 2014. Surgical repair is required in complete full-thickness tears. Surgical complications include reduced knee flexion, quadriceps muscle atrophy, decreased patellar mobility, patellar stiffness and persistent pain [20]. Acute quadriceps tendons repair with the use of sutures through trans-osseous patellar bone tunnels is well established technique [3,21]. Maniscalco et al. published the first report of quadriceps tendon repair with suture anchors with mean knee flexion $0\text{-}120^0$ at two years follow up [12]. Richards and Barber reported a Lysholm score of 88 and a Tegner score of 2 in one patient after an 11-month follow-up with a mean knee flexion $0^0\text{-}125^0$ [11]. Bushnell et al. reported the mean knee flexion of $0\text{-}130^0$ with an 80% complete return to activities of daily living (ADL) [16]. Kerin et al. reported a complete return to sports activity after 8 months [23]. F. Mille et al. reported Tegner score of 2.8 and Cincinnati score of 79.5 with a return to daily activities (ADL) at 1.7 months and sports at 4.5 months [13]. **(Table 3)** Petri M and Dratzidis A et al.[5] showed that suture anchor repairs of quadriceps tendon ruptures showed less gap formation during cyclic loading and sustained higher ultimate failure loads than trans-osseous suture repairs [5]. Ethibond sutures are commonly utilised, with an average diameter of #5 [20], and 5-throw knots optimise square knot security [27]. The knotted sutures can irritate the soft tissues and may loosen over time. The larger needle makes large holes in the native tendon. There is little evidence of osseointegration of the suture material in the bone tunnels, which may increase the risk of patellar fracture [22]. We used a smaller diameter suture with comparable strength to Ethibond, so a #2 fibre wire (Arthrex) was selected. This has high tensile strength and minimises tissue damage compared to ethibond [3]. The addition of a suture anchor for fixation allows for knotless technique and has been shown to have good to excellent pull out strength compared to trans-osseous repair [5]. A second suture with knotless anchor fixation provides additional strength to the repair and may facilitate early mobilisation and loading of the quadriceps mechanism. The fact that the sutures are crossed over means that failure of one anchor does not mean failure of the entire construct as each anchor contains a suture limb form both sides of the tendon. This is a technique that is popular in shoulder surgery [29]. As compared to the trans-osseous technique, the double suture anchor fixation involves smaller skin incision and less tissue trauma, shorter operative time, less soft tissue stripping and disruption of surrounding blood supply and improved healing rates [3]. Besides, there is a decreased risk of major complications, including patella fracture [11,22,24]. These potential advantages must be weighed against the cost-

effectiveness of the procedure, which is in favour of the trans-osseous technique [11]. We evaluated the use of a knotless, crossed, double suture anchor fixation in quadriceps tendon repair. It is a safe and effective technique, and the clinical and radiological results are consistent with published studies.

References	Number	Follow-up (months)	Score	Range of motion	ADL	Sports
Maniscalco et al.	1	24		0-120	Yes	Yes
Richards and Barber	2	11	L 88 T 2	0-125	Yes	
Kerin et al.	1	8		Complete		8 months
Bushnell et al.	5	10.6		0-130	80% complete return	
Mille F et al.	13	15	T 2.8	0-125	1.7 months	4.5 months
			C 79.5			
			L 89.7			
Current study	20	12	T 2.8	0-124	2 months	6 months
			C 79.2			
			L 90			

L Lysholm, *T* Tegner, *C* Cincinnati

Table 3: Summary of the published studies where suture anchors were used to repair quadriceps tendon

Limitations

The small sample size and the lack of a control group are the main limitations of our study.

5. Conclusion

The double suture anchor fixation is a safe and effective novel treatment option in managing quadriceps tendon ruptures. Proposed benefits may include less tendon damage due to smaller diameter suture (2 Fibre wire). Crossing over the ends of the Krackow suture allows two anchor points for each side, medial and lateral. The 45-degree angle of the suture anchors may increase pull-out strength and facilitate enhanced recovery. The knotless technique may lessen knot irritation and reduce wound complications. Further studies are required to validate this hypothesis.

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