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Abstract

Patellar tendon ruptures are infrequent and potentially disabling injuries. These injuries are usually repaired with transosseous suture tunnels. However, this technique can produce a significant gap formation and prolonged postoperative immobilization. Although several techniques have been described to improve the integrity of the repair, the surgical technique of choice is a matter of debate especially when there is tissue loss due to high-energy trauma. This study aims to evaluate the clinical outcomes of patients with acute patellar tendon ruptures due to high-energy trauma treated with a novel construct configuration that includes a suture anchor and a figure-of-eight augmentation with hamstring autograft with medial and lateral reinforcement. To determine the clinical outcomes the International Knee Documentation Committee (IKDC) score was obtained pre-surgery and at 12 months of follow-up. A total of six patients were recruited, with a median age of 27.5 years, five of these were male. Three lesions were in the proximal pole of the tendon, two mid-substance and one was in the junction with tibial tuberosity. The IKDC clinical score significantly increased from pre-surgery to the 12-month follow-up with a median difference of 32.8 (95% CI, 19.5-42.6, \( p=0.0313 \)). Likewise, the patients presented a post-surgery quadriceps strength level with a median of 5/5. All patients had full active knee extension with a median of 0-120 degrees. There was no statistical difference in the range of motion comparing the surgical knee to the contralateral knee (\( p=0.6883 \)). No patient presented any type of reintervention or complication during the follow-up period. The configuration of the construct...
presented in the technique had not been reported before in the literature and combines the advantages of the use of suture anchors and biological augmentation with lateral and medial reinforcement. This technique may be useful in patients with traumatic injuries with and without loss of tissue. Although it is a small series with concomitant injuries, satisfactory clinical results were presented during follow-up.

**Keywords**: patellar tendon, autograft, trauma, suture anchor, hamstring tendons.

**New technique**
- The patellar tendon was repaired using a suture anchor and a biological augmentation with a novel construct configuration
- The configuration of the construct theoretically provides greater resistance to strain and gap formation, increases stability, and allows immediate mobilization of the knee

**Advantages and disadvantages**
- Satisfactory clinical results were obtained with this technique after one year of follow-up
- There is no need for additional surgeries to remove the implants
- This technique may be used for acute repair of native patellar tendon ruptures with and without loss of tissue, and it could be beneficial as reinforcement in the reconstruction of the patellar tendon
- This technique requires the drilling of a horizontal tunnel in the patella even though it is a small tunnel there is a risk of fracture, and the harvesting of the hamstrings produces some morbidity.

**Introduction**

Patellar tendon rupture is an extremely disabling injury that results in the loss of active knee extension [1]. This injury is infrequent and has an estimated incidence of 0.68/100,000 per year and primarily affects middle-aged men [2] and if left untreated, could result in severe disability for patients [3]. The causes of tendon rupture can be divided into traumatic and non-traumatic; the first group includes sports injuries and high-energy injuries, and the second group includes patients with predisposing factors such as repeated microtrauma, systemic disease (diabetes mellitus, renal failure, connective tissue pathology, rheumatologic diseases) or previous total knee replacement [4–6].

The most common locations of patellar tendon rupture are the proximal pole of the tendon, followed by the middle portion of the tendon or mid-substance [7], but may also occur distally at the junction with the tibial tuberosity [8]. The clinical presentation is important for the diagnosis and early identification of the lesion [3]. Usually, there is trauma with knee flexion at 90°. The most common clinical signs are anterior knee pain, patellar elevation, active extension deficit, and hematoma [4,8]. Although the clinical diagnosis is usually satisfactory, the use of diagnostic
images such as radiography, ultrasound, and magnetic resonance imaging is useful to confirm the clinical diagnosis and avoid misdiagnosis [4].

Surgical repair is considered the gold standard of treatment and many techniques for patellar tendon repair have been described in the literature, including end-to-end tendon suture [4], transosseous tunnels [9], suture augmentation [10,11], suture tape [9,12], cerclage wire [11], synthetic ligament [10], and hamstring graft [6,7,13], as well as the use of suture anchors [3,9]. However, the surgical technique of choice is a matter of debate, especially in acute injury with tissue loss [1,4,7].

The most commonly used method is the transosseous tunnels [1,14]. With this method, it is possible to present a gap or average lesion space ranging from 2.94 mm [12] to 6.7 mm [15]. The feared complication of a new rupture has led many surgeons to recommend an extended period of postoperative immobilization of the knee in extension to decrease stress throughout the repair [5,16]. This is a disadvantage to the standard rehabilitation technique because there are evident benefits of early motion, including reduced adhesion, improved knee motion, and promotion of tendon healing with earlier collagen fiber remodeling and increased strength of collagen filaments [17,18]. On the other hand, the end-to-end tendon suture has an average gap formation in the lesion of 4.2 mm and has a high risk of suture rupture using this method alone [11].

Therefore, many authors recommend augmentation techniques, especially in cases where the tendon structure has been reduced and tissue quality is poor such as in
high-energy trauma [19]. The augmentation techniques decrease stress at the repair site, allow early knee motion, and reduce the risk of re-rupture, because of less gap formation [20–22]. Although some of these augmentation methods may have some disadvantages such as requiring a second procedure to remove the implant and increased postoperative stiffness when protective cerclage wire is used [11,23].

Biological augmentations may have a smaller gap formation of even 6 mm compared to transosseous tunnels [24], and this method has the additional benefit that it does not require other surgery to remove the cerclage wire when is used as a protector [19,21,25]. Moreover, it has been demonstrated that hamstring augmentation allows the implementation of an aggressive rehabilitation protocol that includes immediate postoperative mobilization with satisfactory functional results [21,24,25]. Similarly, figure-of-eight augmentation techniques have shown a substantial decrease in gap formation and an increase in the final strength of the repair compared to a common repair technique [17].

In addition, some studies report that suture anchors are biomechanically superior to the use of transosseous tunnels [12,14,16], and presented a smaller gap formation on average of 0.85 mm [12] to 2.92 mm [14]. This allows for a better range of motion and faster recovery compared to other techniques [20]. These potential advantages must be weighed against the cost-effectiveness of the procedure [14].

Considering the above, this study aims:
1. To describe a surgical technique with a novel construct configuration that includes a suture anchor and a figure-of-eight augmentation with hamstring autograft with medial and lateral reinforcement

2. To evaluate the clinical outcomes using this technique in patients with acute patellar tendon ruptures associated with high-energy trauma.

**Methods**

The surgical technique is described, and a retrospective case series is presented. The inclusion criteria were patients older than 18 years old, with complete acute rupture of the patellar tendon associated with high energy trauma diagnosed by radiography and confirmed with preoperative magnetic resonance imaging, which also allowed observing associated injuries such as ligament and meniscal injuries and assessing the rupture site. Patients with a history of systemic diseases such as renal failure, diabetes mellitus, or rheumatologic diseases, in addition to patellar tendinopathy, previous fractures or previous surgical procedures in the knee to be intervened were taken as exclusion criteria. After a stable repair of the patellar tendon was achieved, an arthroscopy was performed to treat the associated injuries. The study was conducted from 2019 to 2020 in a specialized hospital. The medical records of all identified cases were reviewed, and clinical data were extracted (gender, age, mechanism of trauma, anatomical location of the injury, medical history, time elapsed between injury and surgery, follow-up time since surgery, additional procedures performed in the same surgical time, level of satisfaction on a numerical score from 1 to 10 (1 being the lowest satisfaction and 10 being the highest satisfaction), the strength of quadriceps was assessed by Medical Research Council
(MRC) grading, range of motion of the knees (measured by a knee surgeon using a goniometer), complications, and reinterventions. To determine the clinical outcomes of the patients, the International Knee Documentation Committee (IKDC) score was obtained before surgical intervention, and at 12 months post-surgery. The study was approved by the ethics committee of the hospital and was conducted following the principles expressed in the Declaration of Helsinki. All patients were able to understand the nature of their treatment and written informed consent was obtained from the participants.

The GraphPad Prism V.7.0 (San Diego, California, USA) software was used for data analysis. The data were not normally distributed, and it’s presented with median and interquartile ranges (IQR). Nonparametric tests were used. Comparison between two groups was evaluated using the Wilcoxon test for paired samples or the Mann-Whitney U test for unpaired samples. In addition, correlations were performed using Spearman’s test. A value of \( p < 0.05 \) was considered statistically significant.

**Surgical Technique**

The patient is placed supine with a tourniquet on the proximal thigh. A midline incision is made from the lower edge of the patella to 1.5 cm distal to the anterior tibial tuberosity, the tendon injury is exposed, and the rupture site and the tendon conditions are assessed. The hamstrings (semitendinosus and gracilis) are harvested using the closed tendon stripper. The hamstrings are sutured together end-to-end, and each free end of the tendon is sutured using Krackow stitches. In this way, a single graft of greater length is obtained (Figure 1A).
The patellar tendon injury is identified. If the rupture is in the proximal portion of the patellar tendon, a 4-5 mm diameter suture anchor is inserted into the inferior pole of the patella (Figure 1B). Otherwise, if the rupture is in the distal portion of the patellar tendon, a suture anchor is inserted into the anterior tibial tuberosity (Figure 1C). A suture is made in the patellar tendon, starting with a Mason-Allen suture technique, and with each remaining strand, Krackow stitches are made on the medial and lateral border of the patellar tendon, the suture helps to restore normal patellar position. Subsequently, a 5-mm transverse tunnel is drilled in the middle of the patella. Similarly, a transverse tunnel 2 cm posterior to the tibial tuberosity of the 7-mm of diameter is drilled. The suture anchor should not impinge with the tunnels previously made, either the one located in the tibia or the patella as appropriate.

The graft is then initially passed through the patellar tunnel in a figure-of-eight configuration (Figure 1D). The graft is passed through the tibial tunnel and traction is applied to the graft to allow an anatomic position of the patella and is fixed with a 7 mm diameter bioabsorbable screw in this tunnel (Figure 1E), and fixation is done in knee extension. The optimal height of the patella is confirmed by comparing the preoperative knee contralateral images with the intraoperative images obtained by fluoroscopy. The remaining ends of the graft are sutured longitudinally to the patellar tendon and to the edges of the graft itself (Figure 1F), in this way, augmentation of the medial and lateral border of the repaired tendon is performed with a reinforcement of the construct. Passive flexion-extension movements of the knee between 0 and 120 degrees are performed to check the range of motion achieved.
and to ensure adequate fixation, and the knee is wrapped with a soft bandage. The diagram of the surgical technique is presented in Figure 2. The mobilization was allowed as soon as postoperative pain allowed it, without flexion limitation, and crutches were ordered for 6 weeks. Patients walked with partial weight bearing for the first 4 weeks. In general, rehabilitation is focused on isometric quadriceps and hamstring strengthening exercises assisted, increasing the range of motion of the knee and patella. After 6 weeks, full weight bearing, and active full knee mobilization was gradually achieved. Quadriceps strengthening exercises were allowed after 12 weeks with gradually increasing resistance.

**Surgical indications**

- Traumatic patellar tendon ruptures
- Patellar tendon ruptures with and without tissue loss
- Reinforcement of the reconstruction of the patellar tendon

**Contraindications**

- Active infection
- Associate patellar fracture

**Results**

Six patients were recruited. All were treated with the surgical technique described above. None of the patients was older than 40 years at the time of the lesion. All
patients presented high-energy trauma due to traffic accidents in the context of motorcycle riders. The characteristics of the patients are described in Table I.

The IKDC total score and each component parameter such as symptoms, sports activities, function, and activity of daily living were significantly improved when comparing pre-surgery and post-surgery status. The total IKDC clinical score significantly increased from pre-surgery to the 12-month follow-up with a median difference of 32.8 (95% CI, 19.5-42.6, \( p=0.0313 \)) (Figure 3).

No correlations were found between age and IKDC score results nor between the time elapsed between the injury and the surgery and IKDC score results. No differences were found between patients with and without additional ligamentous injuries. Regarding, the level of satisfaction, only one patient reported satisfaction of less than 10. Likewise, the patients presented a post-surgery quadriceps strength level with a median of 5 (Table II).

Regarding post-surgery knee range of motion, all patients had full active knee extension with a median of 0-120 degrees (Table II). There was no statistical difference in the range of motion comparing the surgical knee to the contralateral knee \( (p=0.6883) \). Finally, there were no further interventions or complications during the follow-up period and all patients returned to their normal daily activities and work.
Discussion

The present study analyzed the clinical outcomes of six patients with acute patellar tendon rupture associated with high-energy trauma and treated with the surgical technique described above. The construct configuration in the surgical technique presented had not been previously reported in the literature and is a modification of existing techniques that use suture anchors and biological augmentation. This technique was developed in response to the complexity of injuries occurring in high-energy trauma, where there is tissue loss due to trauma and there are multiple injuries in the knee [26,27]. The main finding of this study was an adequate clinical outcome in the follow-up period even with associated injuries.

These injuries occurred primarily in male patients. All patients presented with high-energy trauma from traffic accidents in the context of motorcycle riders. These gender findings are like those reported in the literature where injuries in females are infrequent [2,7]. In addition, it has been shown that women have greater ligament laxity, which could be a protective factor for the development of these injuries [28]. The mechanism of trauma presented differs from most reports where acute injuries are mainly caused by sports activities and associated with repetitive microtrauma [28,29]. Also, all patients in the series presented are younger than 40 years at the time of injury, similar findings have been reported in some studies where the mean age of acute rupture is 39 years [7,28]. Regarding the location of the injury, proximal injuries are more prevalent in several published studies [1,7,10], as presented in this series.
Associated injuries in patellar tendon rupture are mainly meniscal and anterior cruciate ligament injuries [26,27]. All patients in our series presented with additional injuries requiring surgical repair, this was mainly because they were injuries associated with high-energy trauma where associated injuries are frequent, although meniscal injuries occurred in most of the reported patients, as reported in the literature, additional severe ligamentous injuries were presented (Table I).

Due to the different types of rupture that can occur and the possibility of poor-quality tendon tissue and even loss of tissue associated with trauma, the treating surgeon must always be prepared to obtain the best possible repair, achieving safe and early mobilization of the injured knee, to minimize the complications of surgery [3,7].

Although additional injuries are evident in the series presented and in these cases an adequate clinical assessment is difficult, the patients presented a satisfactory range of motion and quadriceps strength at follow-up (Table II), which are clinical characteristics associated with patellar tendon reconstruction [29]. Some limitations of this study are the small sample size, the lack of a control group, and the presence of multiple knee injuries, although the infrequency of these lesions should be considered, and the presence of multiple knee injuries reflects the reality of the patients with high-energy trauma. The limited number of patients could explain why there was no difference in the IKDC score between patients with additional ligamentous injuries. In addition, there is the limitation of not having the necessary equipment to quantitatively measure quadriceps strength. Likewise, the 12-month
follow-up with the IKDC may be a limitation when evaluating long-term clinical outcomes. It must be considered that this technique required the drilling of a horizontal tunnel in the patella, even though it is a small tunnel there is a risk of fracture and there is a risk of re-rupture of the patellar tendon, or the grafts used. Although a minimal risk, morbidity must be considered in association with the harvesting of the hamstrings [19].

Considering the above, the surgical technique presented uses a hamstring autograft for biological augmentation using a figure-of-eight with medial and lateral reinforcement associated with the use of a suture anchor, this configuration of the construct theoretically provides greater resistance to strain and gap formation, increases stability, and allows immediate mobilization of the knee [12,14,24]. As far as we know there is no biomechanical testing of a repair technique using this configuration of the construct. With this technique, there is no need for additional surgeries for implant removal and the general function, knee stability, symptoms, and satisfaction of the patients presented satisfactory results in the follow-up. Clinical evidence is needed to verify the optimal treatment method for acute patellar tendon rupture in high-energy trauma. This construct configuration may be used in patients with traumatic injuries with and without loss of tissue, and it could be beneficial in selected cases with chronic tendinopathy or failed repair.

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Conflict of Interest

All authors reported no conflict of interest.

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Figure 1. Steps of the surgical technique

A. Union of semitendinosus and gracilis tendons, black arrow indicates end-to-end connection point. B. Insertion of the suture anchor in the inferior pole of the patella, for proximal or mid-substance injuries. C. Insertion of the suture anchor in anterior tibial tuberosity for distal tendon injuries. D. Figure-of-eight configuration of the graft. E. Graft fixation in the tibial tunnel with a bioabsorbable screw, white arrows indicate the remaining ends of the graft. F. Final construct configuration. The remaining ends of the graft are sutured longitudinally to the patellar tendon and to the edges of the graft itself as indicated by the white arrows.

Figure 2. Diagram of the surgical technique

A. Diagram of the surgical technique showing the location of the graft and implants when the lesion is proximal. B. Diagram of surgical technique with a distal lesion.

Figure 3. Comparison of the outcomes of the total IKDC score result and comparison of each IKDC parameter in all patients.

A. Total result of the IKDC. B. Symptoms significantly increased from pre-surgery to the 12-month follow-up with a median difference of 8.6 (95% CI, 1.20-15.0, \( p=0.0313 \)). C. Sports activities significantly increased from pre-surgery to the 12-month follow-up with a median difference of 16.8 (95% CI, 9.20-23.0, \( p=0.0313 \)). D. Function, and activity of daily living significantly increased from pre-surgery to the 12-month follow-up with a median difference of 4.6 (95% CI, 2.30-4.60, \( p=0.0313 \)). Comparisons were made using the Wilcoxon test with a 95% confidence level. The level of significance is shown in the upper part of the figure. (* \( p<0.05 \)).

Table I. Patient characteristics

| IQR: Interquartile range |

Table II. Post-surgery Characteristics

* Medical Research Council Grading
Table I. Patient characteristics

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Table II. Post-surgery Characteristics

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* Medical Research Council Grading
Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: