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TECHNICAL NOTE • KNEE - TRAUMA

Intra-operative patellar fracture during chronic patellar tendon rupture reconstruction: salvage and prophylactic modified techniques

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Abstract
Management of chronic neglected patellar tendon rupture represents a challenging condition for the orthopedic surgeons to deal with due to many factors such as quadriceps muscle atrophy, superior migration of the patella, e.g., patella alta, peri-patellar adhesions and patellar tendon atrophy. Such difficulties might be further complicated by intra-operative patellar fracture during patellar tendon reconstruction. In the current article, the authors report (1) a salvage procedure for such devastating intra-operative complication, based on bypassing the patella and gaining the advantage of the quadriceps tendon for structural and functional restoration of the knee extensor mechanism, and (2) prophylactically a technical modification of patellar tendon reconstruction guarding against such inadvertent patellar fracture.

Keywords Chronic patellar tendon rupture · Neglected patellar tendon rupture · Patellar tendon reconstruction · Intra-operative patellar fracture · Salvage patellar tendon reconstruction

Introduction

Chronic neglected patellar tendon (PT) rupture is a disabling condition as it compromises the knee extensor mechanism. In spite of wide agreement on management goal of such detrimental condition, e.g., restoration of active knee extension with pain-free mobile stable knee joint, the management options remain a debatable evolving issue, especially in light of paucity of literally reported recommendations for such challenging condition. Such challenges are attributed to many points including quadriceps muscle atrophy and contracture, superior migration of the patella, e.g., patella alta, peri-patellar adhesions and PT atrophy and scarring [1–5].

An additional challenge comes from the point that selection of suitable surgical techniques (regarding graft choice and method of fixation) for PT reconstruction is still not well established [1–15].

A part of this work (The technique) has been presented at the Annual International Conference of the Egyptian Orthopedic Association, 2016.

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One challenge (which might have not been reported yet in the literature) is intra-operative fracture patella (due to the poor bone stock) during cerclage wire tensioning to fully reposition the patella back to its bed. Here is the description of (1) *a salvage technique* for such intra-operative challenge which can be effectively reproduced in similar situations and (2) *prophylactically a technical modification* for safe reconstruction of chronic PT rupture.

Patients and methods

Case No. 1: (salvage procedure)

Preoperatively, a male patient of 14 years old presented to outpatient clinic complaining of inability to walk unaided and to actively extend his left knee for 8 months following a penetrating knee trauma. The patient has sought medical advice in a primary hospital where the left knee was X-rayed and unfortunately misinterpreted as no fracture line could be detected. Thus, the wound was debrided and sutured under local anesthesia.

Local examination of the left knee revealed wound scar over the medial side with diffuse hollowness in front and quadriceps muscle wasting. The femoral trochlea was easily felt beneath the skin, meanwhile; the patella was palpated riding high; however, it was feasible to bring it almost back to the femoral trochlea; these findings are demonstrated in Fig. 1a, b. The patient was unable to actively extend this knee while still keeping full passive range of motion (ROM). The provocative tests for meniscal, ligamentous or chondral lesions negated associated pathology.

Further patient evaluation included antero-posterior and lateral X-ray views of both knees; affected (left) knee views revealed patella alta and poorly defined cortical shell, mostly from the inferior patellar pole. Meanwhile, sound (right) knee views were helpful in calculating the Insall–Salvati ratio to aid in preoperative planning, e.g., estimation of normal patellar height of the affected knee. In addition, MRI of left knee revealed quadriceps muscle atrophy with minimal fatty infiltration, patella alta, displaced inferior patellar cortical pole, distally retracted thinned-out PT and no associated meniscal, ligamentous or chondral lesions [16]. Figure 2 demonstrates MRI image of retracted ruptured PT with high-riding patella.

Fig. 2 MRI image of the retracted ruptured patellar tendon (red arrow) with high-riding patella (yellow arrow) (colour figure online)

Operatively, the left knee was initially examined for both passive ROM and ligamentous integrity under spinal anesthesia. After administration of antibiotic prophylaxis, the lower limb was exsanguinated for tourniquet application, followed by formal prepping and draping. A 5-cm skin incision was performed over the antero-medial surface of the proximal tibia, midway between the tibial tubercle and the postero-medial border of the tibia; ipsilateral hamstring (semitendinosus and gracilis) tendons (SGT) were harvested using an open tendon stripper with preservation of their distal (tibial) insertion. The free ends of both tendons were cleaned off the soft tissue and Krackow-sutured to facilitate later passage through the bony tunnels. The length of harvested semitendinosus tendon (ST) was approximately 21 cm, and that of gracilis tendon (GT) was 18.5 cm.

Another 15-cm midline skin incision started from the upper patellar pole down to the tibial tubercle; meticulous release of fibrous tissues and adhesions was performed using sharp and blunt dissections and electrocautery to free the extensor mechanism starting from the quadriceps muscle–tendon junction down to the attachment of the inferiorly retracted PT into the tibial tubercle. When identified, the antero-inferior patellar pole was released and excised. Figure 3a, b demonstrates both surfaces of the antero-inferior patellar pole. Additionally, intra-articular knee examination excluded associated pathology.

Then, under imaging intensifier, the patella was distally pulled to restore the normal Insall–Salvati ratio, both manually and by Kocher clamp. However, it was still infeasible to restore the normal patellar height; thus, cerclage wiring technique was used for effecting more patellar downward traction; for example, a 4-mm guide pin was passed transversely through the patella just below its equator, another similar guide pin was also passed into the proximal tibia

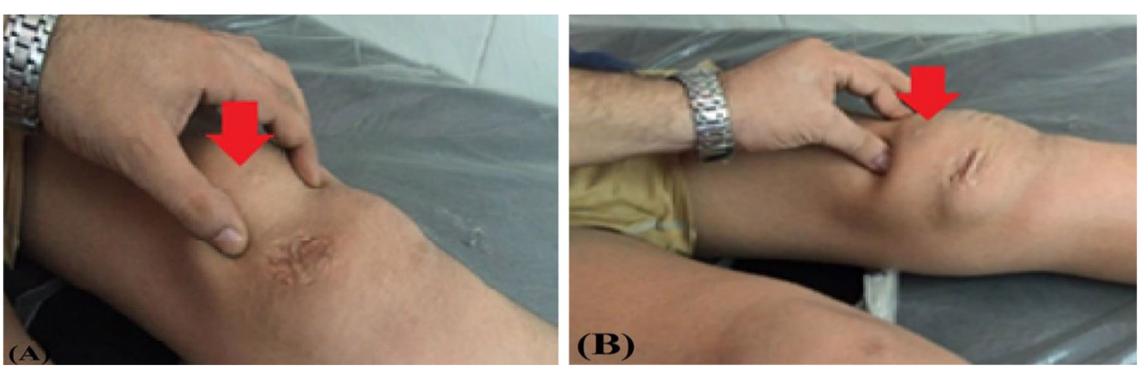

Fig. 1 **a**, **b** Almost feasible manual downward descent of the high-riding patella (red arrows) down to the femoral trochlea (colour figure online)

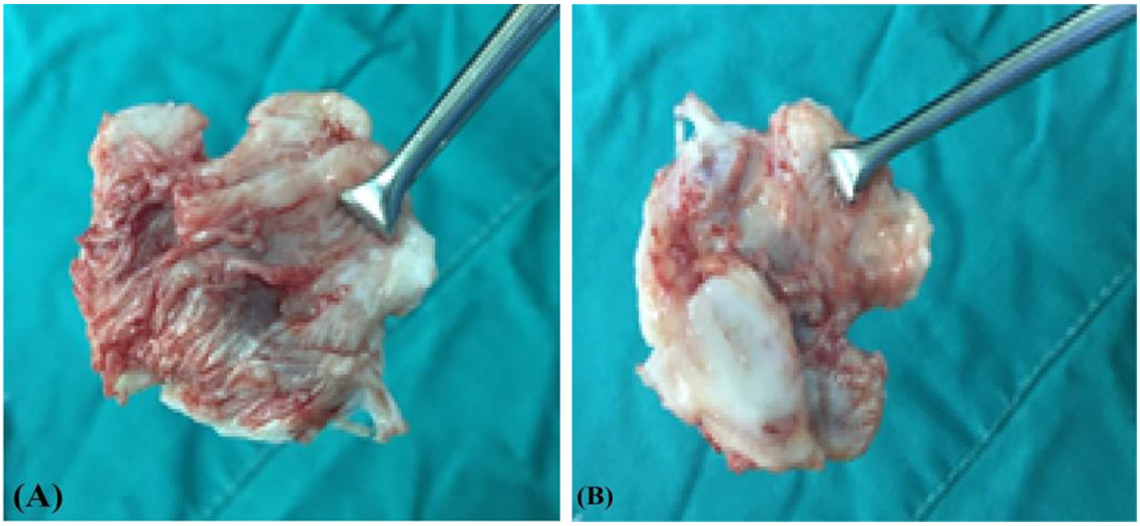

Fig. 3 **a**, **b** Anterior cortical (with the patellar tendon fibers attached to it) and the posterior articular surfaces of the antero-inferior pole of the patella

1.5 cm below the proximal tibial physis and 1 cm posterior to the tibial tubercle, and then, the position of both pins was checked in both coronal and sagittal planes under imaging intensifier. A 4.5-mm cannulated drill bit was passed over these pins to create the patellar and tibial tunnels for passage of cerclage wire and then the SGT autograft [16].

Unfortunately, during cerclage wire tightening, inadvertent incomplete fracture of cortico-cancellous roof of the patellar tunnel occurred, so compromising the integrity of planned bone–SGT autograft construct. Figure 4 demonstrates fracture of the patellar tunnel roof.

Hence, the following salvage technique was performed in which cerclage wire was removed; ST was passed through the tibial tunnel from medial to lateral and then weaved through the quadriceps tendon in lateral-to-medial direction, while the GT was weaved through the quadriceps tendon in medial-to-lateral direction, so forming a tendon graft loop passed proximally through the quadriceps tendon about 1 cm proximal to the upper patellar pole and distally through the tibial tunnel. Then, the free already passed ends of tendons were tensioned to bring the patella down to its bed and sutured over each other by No. 2 non-absorbable sutures.

The proximal stump of the remnant PT was transosseous-sutured back to the inferior patellar pole; then, SGT autograft loop was sutured to the quadriceps tendon, patellar periosteum and the remnant PT. The ST was further secured within the tibial tunnel using a biodegradable interference screw. The restored patellar height was continuously checked under imaging intensifier. Figure 5 demonstrates completed salvage PT reconstruction.

Finally, knee ROM was clinically evaluated to ensure tension-free relaxed reconstructed PT when the knee is extended and to assess the tension exerted over the reconstructed PT during knee flexion to help plan the post-operative rehabilitation protocol. This was followed by closure in layers and application of an above-knee cast.

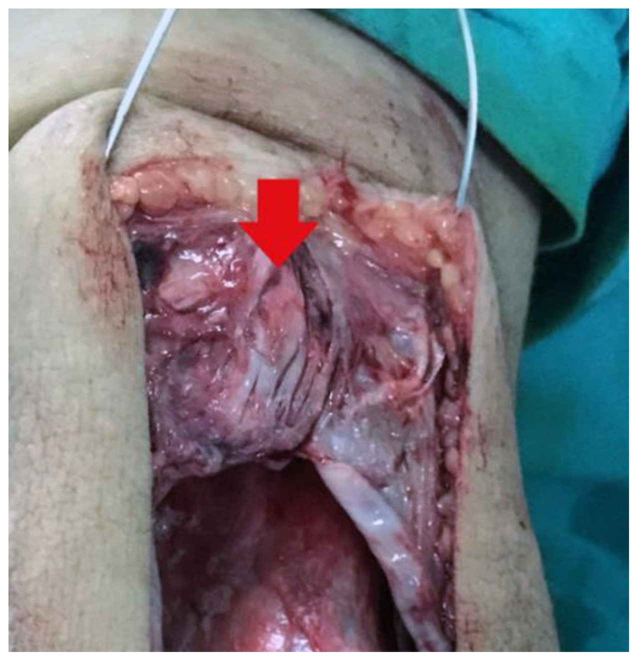

Fig. 4 Fracture of the patellar tunnel roof (red arrow) (colour figure online)

Case No. 2: (prophylactic technical modification)

Preoperatively, a male patient of 15 years old presented with history of 7-month missed PT injury following a penetrating

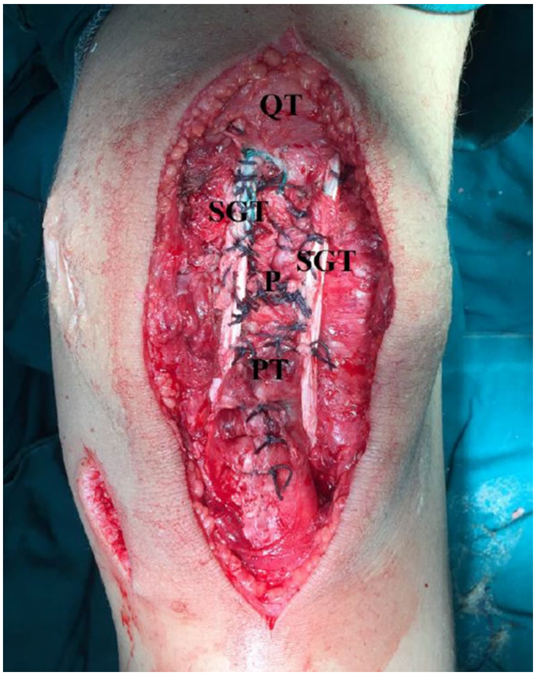

Fig. 5 Completed salvage patellar tendon reconstruction; semitendinosus and gracilis tendon loops were weaved through and sutured to the quadriceps tendon; P, patella; PT, patellar tendon; QT, quadriceps tendon; and SGT, semitendinosus and gracilis tendon autograft loop

trauma to the anterior aspect of his right knee. Figure 6a, b demonstrates findings of patient preoperative examination.

Operatively, the procedure included similar steps of ST harvesting, patellar release and tibial and patellar tunnels; however, the technical modification entailed the use of *ST autograft solely* with preservation of its tibial attachment, passed through a narrower patellar tunnel (*created by 3.2-mm drill bit*) in a medial-to-lateral direction and then through the proximal tibial tunnel in lateral-to-medial direction where it was secured by an interference screw; and then, the already passed free tendon limb was sutured to its attached tendon counterpart. Figure 7a–d demonstrates these technical steps of modified PT reconstruction.

Postoperative rehabilitation

For both salvage and modified techniques, postoperative rehabilitation protocol was based on the intra-operatively achieved knee ROM, e.g., flexion while exerting minimal tension on the reconstructed PT, e.g., 0°–30° knee flexion. Hence, patients were casted in 30° knee flexion for 4 weeks during which non-weight bearing ambulation and isometric quadriceps exercises were encouraged. Then, the cast was replaced by a locked hinged knee brace, progressively increasing weight bearing was allowed and passive and stretching knee exercises were instructed with gradually increasing knee flexion over the next 6 weeks. Once achieving full passive ROM of knee flexion–extension compared to the contralateral side (about 10 weeks postoperatively), rehabilitation was advanced to strengthening exercises of quadriceps, hamstring and calf muscles over another 10 weeks. Eventually, this protocol was completed by neuromuscular coordination exercises over another 4–6 weeks.

Results

Case No. 1

Two-year postoperative evaluation revealed inconstant slight pain only on severe exertion, active ROM of (0°–140°), 0° extension lag with quadriceps girth and knee extension power comparable to the contralateral side. In addition, the Lysholm knee score improved to 94 from 44 points preoperatively. Radiographically,

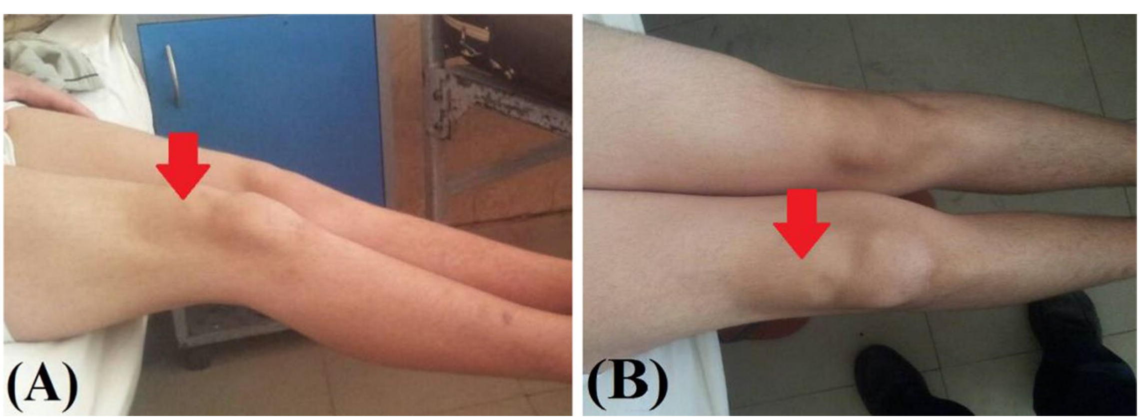

Fig. 6 **a**, **b** Preoperative examination findings of the modified patellar tendon reconstruction case; patella alta (red arrows) and 40° extension lag (colour figure online)

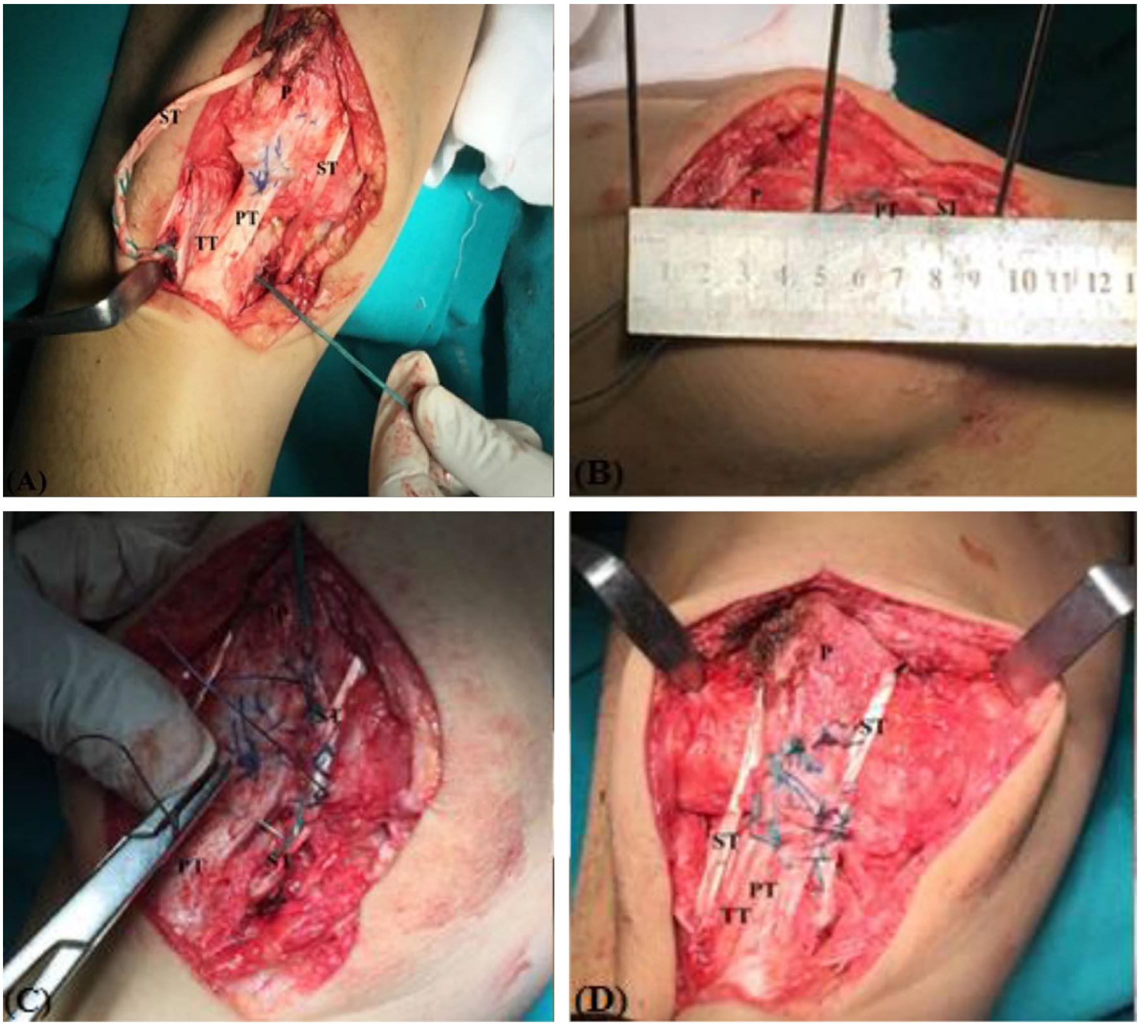

Fig. 7 **a–d** Technical steps of modified patellar tendon reconstruction; **a** passage of semitendinosus tendon through 3.2-mm patellar tunnel and then though proximal tibial tunnel; **b** clinical evaluation of restored normal Insall–Salvati ratio; **c** suturing of the semitendinosus tendon loop to the re-attached patellar tendon and to the patellar retinacula; **d** completed modified patellar tendon reconstruction; P, patella; PT, patellar tendon; ST, semitendinosus tendon autograft; and TT, tibial tubercle

immediate and follow-up X-ray revealed adequate restoration of the patellar height according to Insall–Salvati ratio.

Case No. 2

Ten-month postoperative assessment unveiled inconstant slight pain only on severe exertion, active ROM of (10°–130°), 10° extension lag with quadriceps girth and knee extension power mostly comparable to the contralateral side. In addition, the Lysholm knee score improved to 86 from 42 points preoperatively.

Discussion

Patellar tendon rupture is a rare, however the third most common incapacitating condition of the knee extensor mechanism following fracture patella and quadriceps disruption. It mainly affects young active patients below the age of 40 years. Studies report both (a) traumatic (penetrating) and (b) non-traumatic mechanisms of PT rupture. The later mechanism represents an interplay of sudden forcible eccentric quadriceps contraction of a knee being brought into resisted early flexion (e.g., landing from a height) commonly on top of preexisting poor-quality PT tissues, which in turn might be caused by either generalized (e.g., diabetes mellitus, chronic renal failure, hyperparathyroidism and rheumatoid diseases), or local factors (e.g., following total knee replacement, bone–patellar tendon–bone harvesting for anterior cruciate ligament reconstruction, excision of infrapatellar bursitis and local steroid injection). Such interplay ends in PT rupture most commonly from the inferior patellar pole [1, 3, 5, 8, 17, 18].

Classically, ruptured PT is acutely (early) repaired to effectively restore knee extensor mechanism by Krackow-fashioned non-absorbable sutures passed through three vertical patellar tunnels or alternatively by more recently suture anchors inserted into the inferior patellar pole with debatable biomechanical and clinical outcomes. Some authors recommend tendon repair either protection by cerclage wire or augmentation by looped SGT autograft, especially for poor-quality PT tissues (e.g., rheumatoid diseases) or acute re-rupture of repaired PT [5, 19–24].

In more rare situations, such acute PT rupture might be missed due to poor examination, especially in polytrauma and in obese patients and in cases of knee trauma with massive effusion and/or extensive ecchymosis, leading to chronic neglected PT rupture, e.g., delayed operative intervention more than six weeks [1, 2, 5, 12, 17, 25].

In such chronic rupture, PT repair usually yields unfavorable outcomes; hence, most of the authors recommend PT reconstruction coupled with re-attachment of the remnant native PT to the inferior patellar pole, literally describing widely various debatable techniques in spite of rarity of such chronic ruptures, nevertheless reporting no conclusive recommendations [1–15].

Technically, the debatable difficulties encountered when managing a case of chronic neglected PT rupture include the following points;

1. Restoration of the inherent patellar height, rotation and tracking which may be hindered by quadriceps atrophy and contracture, patella alta, peri-patellar adhesions and scarring and PT retraction, attenuation and fibrosis. Different techniques have been reported for safe and effective patellar relocation whether preoperatively as patellar pin traction, external fixation and Ilizarov techniques, or intra-operatively as excision of the medial and lateral sulci of supra-patellar bursa, sub-periosteal dissection of vastus intermedius from the front of the femur, medial and lateral para-patellar retinacular release (with increased risk of patellar devascularization, necrosis and osteoporosis), traction, cerclage wiring and quadriceplasty. On contrary, overzealous patellar relocation may end in patella infera [1, 2, 10, 11, 17, 18, 26].
2. The graft choice for reconstruction with much controversy on the use of tendon autografts (most commonly ipsilateral ST and/or GT with and without preservation of their tibial insertion, reversed quadriceps tendon with patellar bone block or Achilles tendon, or contralateral bone–patellar tendon–bone); tendon allografts (Achilles tendon or bone–patellar tendon–bone); or synthetic materials [1–13, 15].
3. The methods of graft fixation, e.g., transosseous sutures/tunnels, staples, suture anchors and interference screws [1–15].
4. The need for early postoperative temporary protection of the newly reconstructed tendon, e.g., well-tensioned looped graft at 30° knee flexion; cerclage wire (removed by 6 months postoperatively); or turnover flap of the quadriceps extension. In addition, Gomez et al. reported PT reconstruction with central one-third of the quadriceps tendon postulating that such harvesting promotes quadriceps inhibition, thus protecting the reconstruction during early recovery period [1–5, 8, 10, 27].
5. The pace of postoperative rehabilitation implemented under two opposing parameters: (a) the need for early knee motion and weight bearing to guard against knee stiffness and exaggeration of quadriceps atrophy versus (b) the need for decreasing the stresses across the reconstruction site to lower the risk and the size of gap formation (or even acute re-rupture) with subsequent extension lag, thus ensuring more sound reconstructed tendon healing and better histological, biomechanical and functional outcomes [1–5, 8–10, 12, 27, 28].

In addition, there are no available publications on techniques employed for inadvertent patellar fracture management during PT reconstruction. The currently reported patellar tunnel cortico-cancellous roof fracture could be explained by excessive cerclage wire tensioning in concurrence of poor patellar bone stock due to long-standing immobilization. It is needless to report that the preoperative feasibility of manual patellar descent almost back to its bed negated the need for preoperative traction, as demonstrated in Fig. 1a, b.

The reported salvage technique is based on bypassing the cracked patella and gaining the advantage of quadriceps tendon through which looped SGT autograft is passed, weaved and then sutured into the quadriceps tendon, the patellar periosteum and the re-attached PT remnant achieving firm fixation of looped autograft for structural and functional restoration of the knee extensor mechanism.

While achieving clinical and radiological outcomes comparable to those reported in the literature, such simple and reproducible salvage procedure offers some advantages as bypassing the weak patella to a relatively stronger another structure of the knee extensor mechanism, suturing the remnant PT back to the inferior patellar pole, firmly fixing ST within the tibial tunnel by an interference screw, temporary use of cerclage wiring, so that no need for a later procedure for wire removal, and use of tendon autograft (with minimal harvesting site morbidity), so negating the need for allograft. In addition, preservation of tibial attachment of SGT autograft offers a *biological advantage* of keeping SGT vascularized, thus accelerating tendon loop-bone healing, and also a *biomechanical advantage* of firm tibial attachment, so adding more initial stability to reconstructed PT during early healing phases [4].

Recently, Samagh et al. published a somehow similar technique for PT reconstruction in 25-year-old diabetic obese male patient who sustained knee injury during basketball activity. In their technique, ipsilateral ST tendon was harvested with detachment of its distal insertion, passed through a tibial tunnel, then weaved through the quadriceps tendon and re-passed through the tibial tunnel. Compared to the currently reported technique, Samagh et al. used 2 (instead of 1) interference screws for ST tendon fixation within the tibial tunnel, e.g., one in medial-to-lateral direction and the other screw in an opposite direction. In addition, the reconstruct was augmented by X-shape fashioned fiber tape fixed at the inferior patellar pole and at tibial tubercle by suture anchors. By 6 months postoperatively, this patient achieved active ROM of (0°–120°) with no extension lag and was able to return to sports activity [29].

However, such intra-operative patellar tunnel fracture is better to be avoided by early proper diagnosis of acute PT rupture (e.g., palpable defect distal to high-riding patella, X-ray, ultrasound examination and MRI), more precise assessment of patellar bone stock, encouraging preoperative assisted ambulation and physiotherapy, more extensive intra-operative soft tissue release, quadriceplasty, gradual and gentle cerclage wire tensioning and even staged procedures.

Additionally, a technical modification of PT reconstruction can be employed for long-standing cases with poor patellar bone stock. This technical modification is to use smaller-diameter drill bit of 3.2 mm for the patellar tunnel, which is much narrower than that of 7 mm reported by Zwaal et al., with passage of one, instead of two, hamstring tendon autograft, e.g., ST through such tunnel. Such modification was applied in a subsequent similar case of chronic PT rupture, whereas PT was safely reconstructed (without patellar fracture) while restoring normal Insall–Salvati ratio and achieving satisfactory outcomes by 10 months postoperatively. Figures 8a, b and 9a–c demonstrate preoperative and postoperative Insall–Salvati ratio and postoperative ROM and 10° extension lag of the modified PT reconstruction case, respectively. Such clinical and radiographic outcomes are comparable to those reported for other techniques [1, 2, 4, 16].

A closely similar technical modification was published earlier by Nguene-Nyemb et al. for a case of male patient of 49 years old with PT re-rupture, reporting 2-year satisfactory outcomes in terms of full ROM, normal quadriceps girth and power and return to both daily-living and sport activities. Nevertheless, compared to the currently reported technical modification, Nguene-Nyemb et al. harvested ST solely with preservation of its tibial attachment; however, no tibial tunnel was drilled; they performed two patellar tunnels (4.5 mm tunnel in the lower half of the patella for non-absorbable suture passage used for re-insertion of ruptured PT and 6 mm tunnel in the upper half of the patella for ST passage) and then protected the reconstructed tendon by a sutured fold of the quadriceps extension [3].

For revision cases, Maffulli et al. reported a technique for PT reconstruction following failed repair of ruptured PT, in which ipsilateral hamstring tendon autograft was harvested, passed through a transverse tunnel in the patellar mid-portion and firmly secured to the openings of this tunnel with non-absorbable sutures [30].

In contrary to recommendations of Kim et al. of PT reconstruction without tibial tunnel for preadolescent patients, the currently reported techniques were performed in skeletally

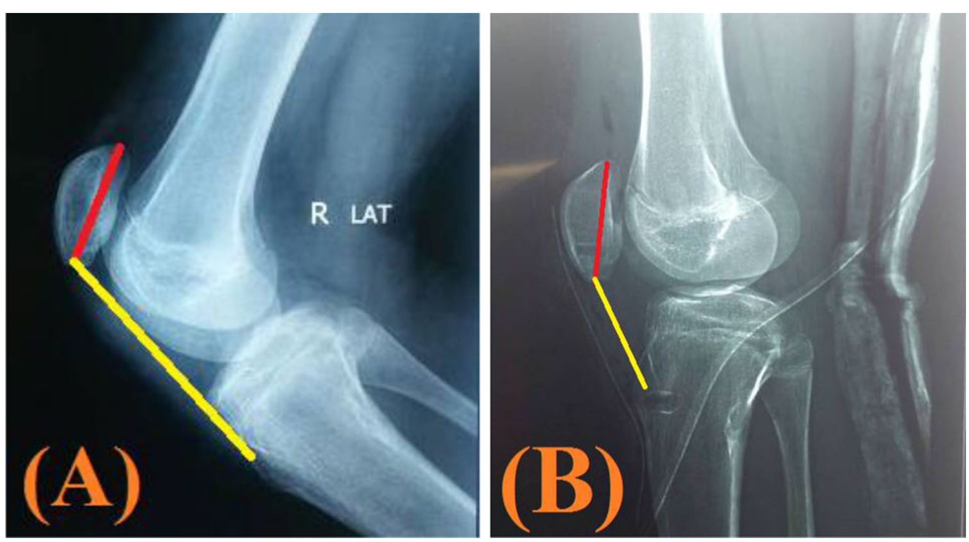

Fig. 8 **a**, **b** Preoperative and postoperative Insall–Salvati ratio of the modified patellar tendon reconstruction case

Fig. 9 **a–c** 10-month preoperative range of motion and 10° extension lag of the modified patellar tendon reconstruction case

immature patients and entailed tibial tunnel positioned safely 1.5 cm inferior to the proximal tibial physis with comparable clinical and radiological outcomes [31].

Nevertheless, postoperative rehabilitation protocol can significantly affect the functional outcomes, so it must be well planned and well supervised by the surgeon himself according to intra-operative integrity of tendon reconstruction and achieved tension-free knee flexion and post-operative patient compliance.

It is needless to admit that rarity of post-traumatic chronic neglected PT rupture cases, especially when complicated with intra-operative patellar fracture, makes it difficult to have conclusive management recommendations; however, this might be the first report of such intra-operative complication and of its salvage procedure during PT reconstruction.

Conclusion

Intra-operative patellar fracture during reconstruction of long-standing chronic neglected patellar tendon rupture is a devastating complication which can be effectively managed by hamstring tendons autograft; harvested with preservation of their tibial attachment; and passed distally through a tibial tunnel and proximally through the bulk of the quadriceps tendon, with accepted restoration of the patellar height. Such salvage procedure coupled with a well-supervised postoperative rehabilitation protocol can achieve satisfactory functional outcomes.

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Authors' contribution All authors have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content and (3) final approval of the version to be submitted.

Compliance with ethical standards

Conflict of interest The authors, their immediate family, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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