Original Article

Adjustable Cortical Fixation Repair Is a Safe and Effective Technique for Quadriceps Tendon Rupture

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Purpose: To report the clinical outcomes of quadriceps tendon repair using adjustable cortical fixation devices at a minimum 2-year follow-up. **Methods:** A retrospective chart review identified patients who underwent quadriceps tendon repair using adjustable cortical fixation devices between January 2017 and March 2020. Patients with a partial tendon rupture were excluded. Demographic and injury-specific variables were gathered preoperatively and postoperatively from the electronic medical record and patient-reported outcomes (Lysholm Knee Questionnaire, Lower Extremity Functional Scale, and SF-12) were collected via telephone at a minimum of 2 years postoperatively. **Results:** Fourteen quadriceps tendon repairs were included in a total of 13 patients. The average time to follow-up was 3.5 ± 1.2 years with a range of 1.9 to 5.7 years. The mean age of this cohort was 55.7 ± 11.6 years, and the mean body mass index was 32.9 ± 6.0. Ten injuries (71.4%) were sustained by mechanical fall, 2 patients (14.3%) suffered a direct blow to the knee, and 2 patients (14.3%) reported a noncontact injury mechanism. Thirteen quadriceps ruptures (13/14, 92.9%) underwent surgery within 10 days of their injury. One knee (7.1%) had a postoperative extensor lag of 5°, whereas another knee (7.1%) required a reoperation for manipulation under anesthesia and arthroscopic lysis of adhesions at 3 months' postoperatively. None of the included patients (0.0%) developed a tendon re-rupture, venous thromboembolism, delayed wound healing, surgical-site infection, neuropraxia or nerve injury, hardware irritation, patella fracture, or heterotopic ossification. **Conclusions:** In this study, adjustable cortical fixation was a safe and effective surgical technique for quadriceps tendon repair, with adequate restoration of quadriceps function and a low rate of adverse events at 2 years postoperatively. **Level of Evidence:** Level IV, therapeutic case series.

The most effective surgical technique for management of quadriceps tendon rupture remains unknown. Conventional techniques for quadriceps tendon repair use either transosseous tunnels or suture anchors to achieve tendon—bone fixation, and these methods have demonstrated comparable results with regard to clinical outcomes, functional outcomes, and adverse events.[1-3] However, fixation failure continues to be a clinical concern, with tendon re-rupture rates of 3% to 5% reported in the literature.[4] A substantial number of patients also experience functional deficits with regard to muscle atrophy, quadriceps strength, extensor lag, and range of motion (ROM) following both transosseous and suture anchor repair of the quadriceps tendon.[5-9]

Adjustable cortical fixation repair has been proposed as an alternative surgical technique for acute ruptures of the quadriceps tendon.[10] Previous cadaveric studies investigating adjustable cortical fixation devices have demonstrated superior biomechanical properties compared with the conventional techniques for quadriceps tendon repair.[10] The use of adjustable cortical fixation is theoretically advantageous because it allows the surgeon to tension and retension the repair

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intraoperatively while performing cyclic knee flexion. Moreover, adjustable cortical fixation devices allow for the creation of a "self-tensioning" construct, whereby any gap formation that occurs postoperatively will further tighten the repair at the tendon–bone interface.

Multiple previous clinical studies have established adjustable cortical fixation as a viable fixation option for ankle syndesmosis repair,[11] cruciate ligament reconstruction,[12] and acromioclavicular joint dislocation.[13] However, there is a lack of clinical data pertaining to adjustable cortical fixation devices in the setting of quadriceps tendon rupture. The authors were only able to identify one case report[14] that used adjustable cortical fixation for acute quadriceps tendon repair and one small case series that explored the use of adjustable cortical fixation devices as an augment to conventional patellar tendon repair techniques.[15]

The purpose of this study was to report the clinical outcomes of quadriceps tendon repair using adjustable cortical fixation devices at a minimum 2-year follow-up. The authors hypothesized that adjustable cortical fixation repair would be associated with favorable patient-reported outcome scores and a low adverse event rate at 2 years' postoperatively.

Methods

Study Design

A retrospective chart review was performed to identify all consecutive patients who underwent adjustable cortical fixation repair for a complete quadriceps tendon rupture between January 2017, and March 2020. Patients who sustained a partial tendon rupture or underwent surgical repair using a different technique (eg, transosseous tunnels, suture anchors) were excluded. Surgical indications included a complete quadriceps tendon rupture at or near the superior pole of the patella that was confirmed by magnetic resonance imaging, with clinical examination findings of a palpable tendon gap, extensor lag, and/or inability to perform a straight leg raise against resistance. All operative procedures were performed by the senior author (M.H.M.), a fellowship-trained orthopaedic sports medicine surgeon, at a single institution during the defined study period. Institutional review board approval was obtained before study initiation.

Operative Technique

Surgical dissection was carried out to identify the site of quadriceps tendon rupture at or near the superior pole of the patella. Adequate exposure was obtained including both the superior and inferior poles of the patella, due to the transosseous nature of the repair technique. Postinjury hematoma was evacuated and the tendon stump was debrided of any devitalized tissue. The bony attachment site at the superior patellar pole was also debrided in a similar fashion.

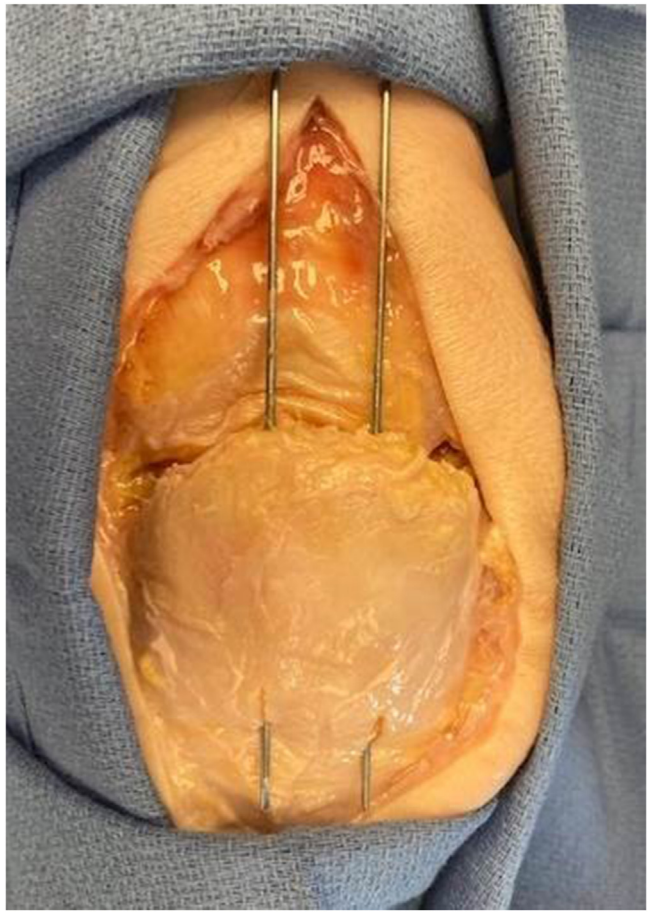

Fig 1. Two 2.4-mm K wires drilled in parallel from the superior pole to the inferior pole of the patella.

Two 2.4 mm K-wires were drilled in parallel from the superior to inferior patellar pole, with specific care taken to avoid the avoid the cartilage surface at the patellofemoral joint (Fig 1). One K-wire was placed in the medial-third of the patella, and the other was placed in the lateral-third. A #15 scalpel was used to create two 1-cm longitudinal splits in the patellar tendon to permit retrieval of the exiting K-wires. The 2 K-wires were then sequentially removed and simultaneously exchanged with a Hewson suture passing device, exiting out the superior pole (Fig 2). The suture passing device, in turn, was used to shuttle two #0 high-tensile strength sutures (FiberWire; Arthrex, Naples, FL) through the tunnels, such that the looped ends of the high-tensile strength sutures were extruded from the inferior pole and the free ends were extruded from the superior pole.

Two adjustable cortical fixation devices (ACL TightRope; Arthrex) were then shuttled through the transosseous tunnels in a retrograde fashion, from the inferior pole to the superior pole. Both the adjustable loop

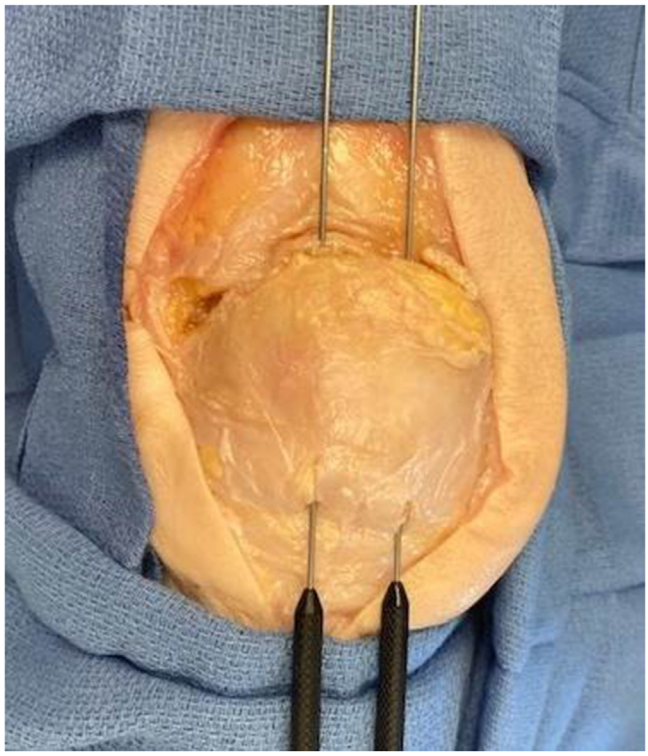

Fig 2. Two Hewson suture passers placed through the patella from the inferior pole to the superior pole.

component of the device and the lagging/tensioning strands were passed at this stage. The leading strands were used to seat the cortical fixation button in an appropriate position at the inferior patellar pole, directly on bone and completely beneath the patellar tendon fibers to minimize hardware prominence (Fig 3).

Attention was turned to the distal aspect of the quadriceps tendon. Two strands of #0 high-strength suture tape (FiberTape; Arthrex) were used to create 2 running non-locking stitches in a modified Bunnell weave configuration, with one running stitch placed in the medial-third of the quadriceps tendon and the other placed in the lateral-third (Fig 4). Each stitch was started proximal in the quadriceps tendon (just distal to the musculotendinous junction), then progressed distally to the tendon rupture site, where the suture tape was used to secure the adjustable loop to the tendon. Each running stitch was then continued back proximally and handtied at the level of the initial starting point (Fig 5).

Finally, the lagging/tensioning strands of the adjustable cortical fixation device were then passed through the quadriceps tendon (from posterior to anterior), placed medially and laterally to each of the 2 running stitches (Fig 6). The lagging/tensioning strands were pulled forcefully to reduce the distal aspect of the quadriceps tendon to the superior pole of the patella. The repair construct was then pretensioned by cycling the knee 5 times from 0 to 90° flexion. The lagging/tensioning strands were again pulled forcefully to retension the construct. This process was repeated sequentially until the knee could be cycled to 90° flexion without any visible tendon gap formation. The lagging/tensioning strands were then handtied over the running stitch in a horizontal mattress configuration to complete the procedure, thereby creating a "self-tensioning" repair construct (Fig 7). The torn retinaculum was repaired using #2 high-tensile strength suture (FiberWire; Arthrex), the surgical site was irrigated copiously, and layered closure was performed using 2-0 VICRYL (Ethicon, Somerville, NJ) and 3-0 MONOCRYL suture.

Postoperative Rehabilitation

All patients were placed into an extendible hinged knee brace immediately following the operation. They were allowed to bear weight as tolerated on their operative extremity with the brace locked in extension (zero degrees). Physical therapy was initiated during the first week postoperatively. The patients were

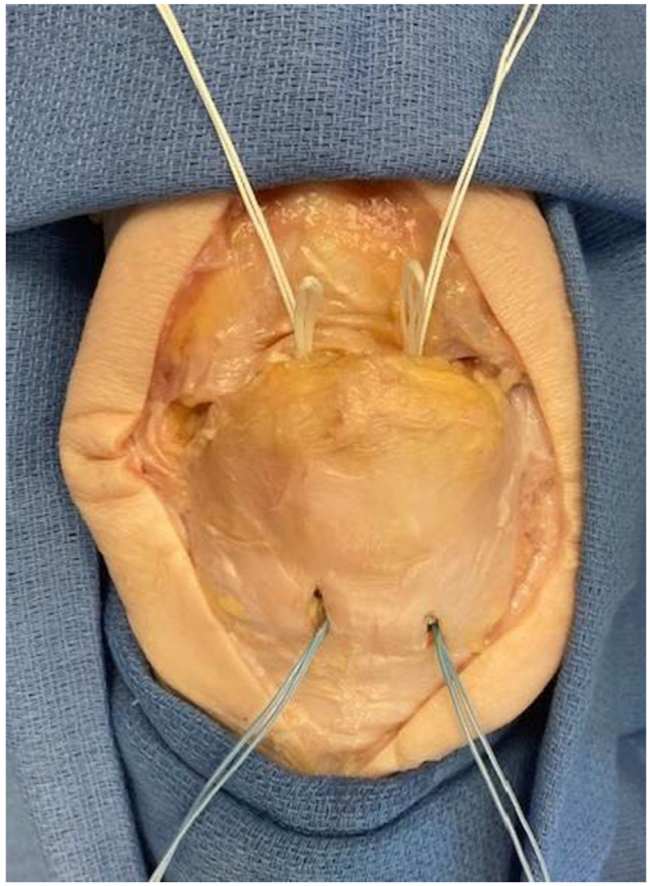

Fig 3. Two adjustable cortical fixation devices placed in appropriate position. The cortical fixation buttons and leading strands are located at the inferior patellar pole. The adjustable loops and lagging/tensioning strands exit through the superior patellar pole.

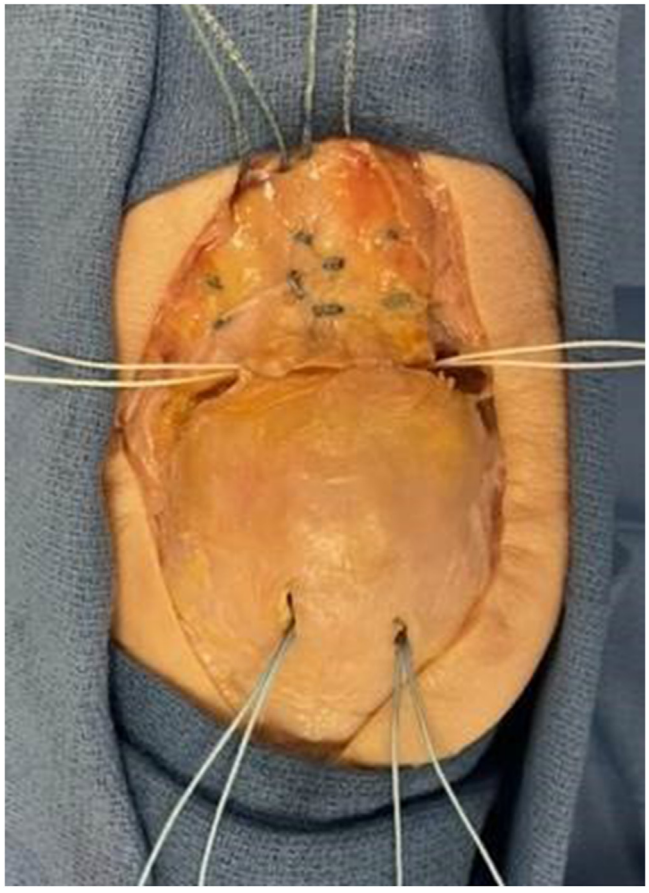

Fig 4. Two running, nonlocking sutures placed in the quadriceps tendon, entering and exiting the tendon just distal to the musculotendinous junction.

encouraged to progress their knee flexion in a stepwise fashion under the supervision of their physical therapist, with the goal of achieving 90° of flexion by the 1-month postoperative time point. Patients were then transitioned from their extendible hinged knee brace to a functional knee brace, which was maintained between postoperative months 1 to 3 as a protective measure during the rehabilitation process. Quadriceps-strengthening exercises began at 3 months' postoperatively, and the patient was allowed to begin a progressive return-to-sport program.

Data Collection and Analysis

Several demographic variables were collected from the electronic medical record, including age at the time of surgery, race, sex, body mass index (BMI), tobacco use, alcohol abuse, preoperative narcotic use, and comorbid medical conditions. Injury- and surgery-related variables also were collected, including mechanism of injury, diagnosis, laterality, tendon rupture site, workers' compensation status, number of days between injury and surgery, operative procedure, and intraoperative complications. Finally, postoperative variables were collected from the electronic medical record, including knee ROM at the final clinic visit, presence of extensor lag, re-rupture of the operative tendon, reoperation on the ipsilateral knee, and postoperative complications or adverse events such as venous thromboembolism, delayed wound healing, surgical-site infection, neuropraxia or nerve injury, hardware irritation, patella fracture, and heterotopic ossification. At a minimum of 2 years' postoperatively, attempts were made to prospectively contact all subjects by telephone to collect the following patient-reported outcomes: Lysholm Knee Scoring Scale, Lower Extremity Functional Scale, and 12-item Short Form Survey (SF-12), which includes both Mental and Physical components. After patient identity was confirmed, standardized descriptions of physical ability, limitations, and pain were described to patients before and during survey questioning. This step was undertaken in an attempt to minimize bias and maximize reliability and accuracy of patient responses.

Descriptive statistics were performed on each of the aforementioned variables. Number and percent were reported for categorical variables. Mean and standard deviation were reported for continuous variables.

Results

A total of 13 patients were enrolled in this study, one of whom sustained bilateral quadriceps tendon ruptures

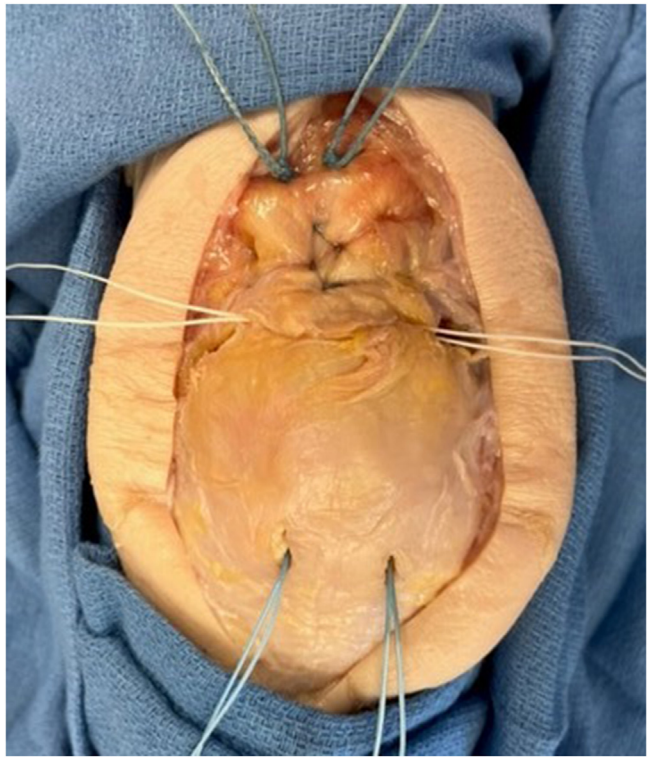

Fig 5. Two running, nonlocking sutures tied proximally in the quadriceps tendon.

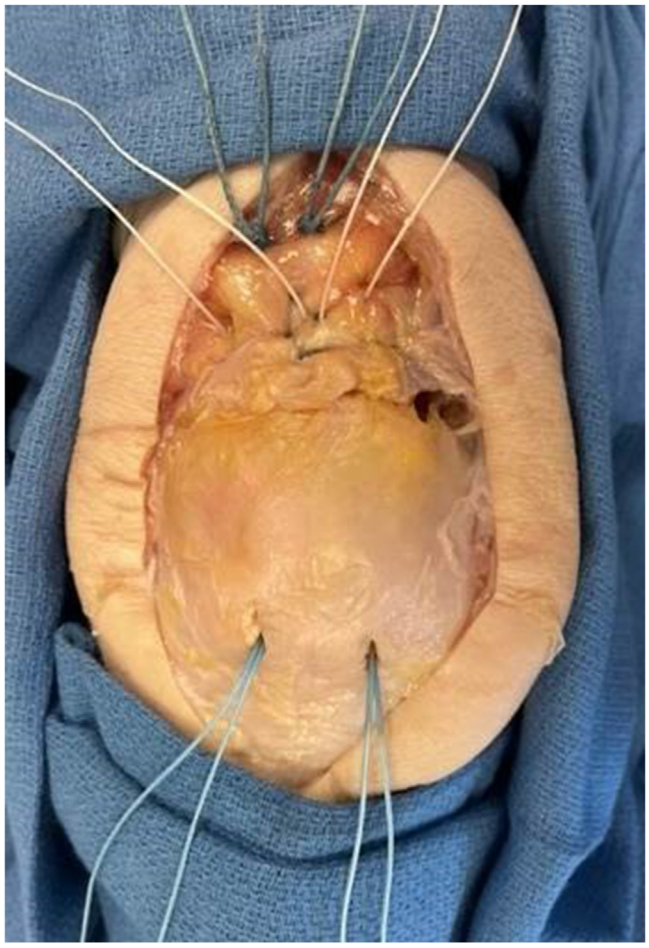

Fig 6. Four lagging/tensioning strands of the adjustable cortical fixation device passed through the quadriceps tendon and exiting the tendon anteriorly, just medial and just lateral to each of the 2 running stitches.

resulting in 14 quadriceps tendon ruptures available for analysis. All but one of the affected patients were male (12/13; 92.3%), with a mean age of 55.7 ± 11.6 years. The average time to follow-up was 3.5 ± 1.2 years with a range of 1.9 to 5.7 years. Nine of the subjects were White (9/13; 69.2%), 3 were African-American (3/13; 23.1%), and the 1 remaining subject identified as American Indian or Alaskan Native (7.7%). The mean BMI of this study cohort was 32.9 ± 6.0. None of the injuries (0.0%) were classified as a workers' compensation case. Ten quadriceps tendon ruptures were sustained during a fall from standing height (10/14; 71.4%), whereas 2 were the result of a direct blow to the knee (2/14; 14.3%) and 2 occurred through a noncontact mechanism of injury (2/14; 14.3%). Thirteen surgical procedures were performed within 10 days (13/14; 92.9%) of the injury, whereas the 1 remaining patient (7.1%) underwent surgery 82 days after the date of injury. Of the 14 quadriceps tendon repair procedures, 3 repairs (21.4%) were performed concomitantly with an arthroscopic partial meniscectomy. There were no intraoperative complications (0.0%).

All 13 patients with 14 quadriceps tendon ruptures were included in the assessment of postoperative clinical outcomes. At the final postoperative follow-up visit, 1 knee (7.1%) that underwent surgery at 82 days following injury had an extensor lag of 5°, whereas all other knees (92.9%) were able to achieve full active extension of 0°. Of the 14 quadriceps repairs available for follow-up, there were 2 postoperative adverse events (14.3%). One patient sustained a fall from standing height onto the operative knee that resulted in a superficial wound dehiscence on postoperative day 45. The dehisced part of the surgical wound was sutured in the emergency department and healed appropriately without any further operative intervention. Another patient developed stiffness during the postoperative follow-up period, requiring a return to the operating room for manipulation under anesthesia and arthroscopic lysis of adhesions on postoperative day 92. None of the included patients (0.0%) sustained a

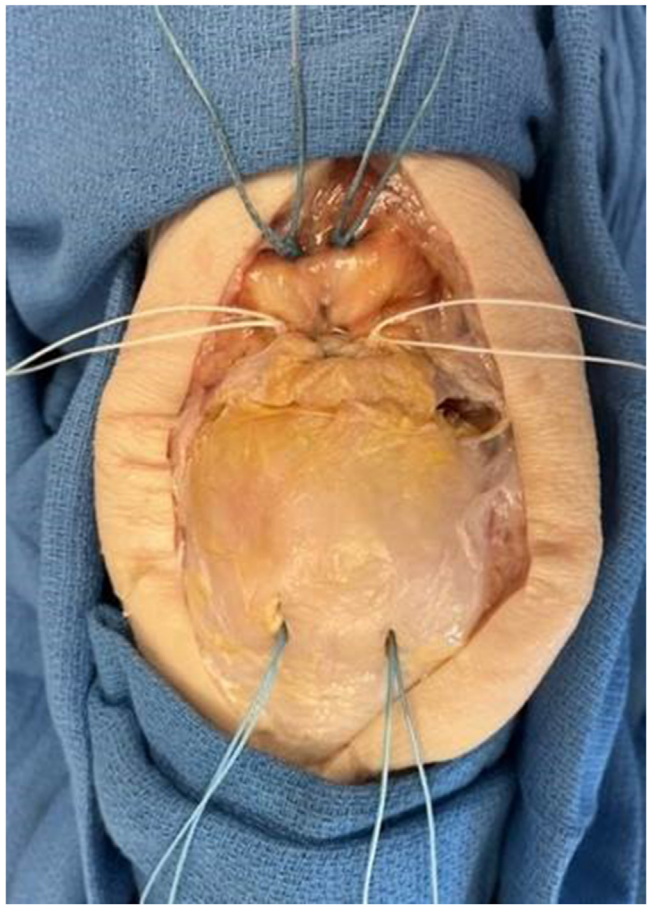

Fig 7. Final quadriceps tendon repair construct, with the lagging/tensioning strands of the adjustable cortical fixation device handtied over the 2 running stitches.

re-rupture of the ipsilateral tendon during the follow-up period. Likewise, there were no instances (0.0%) of venous thromboembolism, delayed wound healing, surgical-site infection, neuropraxia or nerve injury, hardware irritation, patella fracture, or heterotopic ossification.

During the process of contacting patients to complete the patient-reported outcome questionnaires, 1 patient (7.7%) in the study cohort was found to be deceased. Of the remaining 12 patients, 11 (91.7%) completed the requested self-report questionnaires at a minimum of 2 years postoperatively resulting in 12 total knees for analysis. The mean Lysholm score was 86.7 ± 13.02, with 6 knees (50.0%%) achieving an "excellent" outcome, 2 knees (16.7%) achieving a "good" outcome, and 3 knees (25.0%) achieving a "fair" outcome.[16] One knee (8.3%) in this cohort did not achieve a satisfactory outcome (Lysholm score of 64 or lower). The mean Lower Extremity Functional Scale score was 64.1 ± 14.5, mean SF-12 Mental Component score was 56.5 ± 8.6, and mean SF-12 Physical Component score was 42.4 ± 12.2.

Discussion

The most important finding of this study is that adjustable cortical fixation repair was a safe and efficacious technique for the surgical management of quadriceps tendon ruptures. Patients who underwent quadriceps tendon repair using adjustable cortical fixation devices experienced a low adverse event rate, reoperation rate, and tendon re-rupture rate within the defined study period. Most patients achieved an acceptable clinical outcome with regard to extensor mechanism function and patient-reported outcome scores at a minimum of 2 years' postoperatively.

In comparison with the conventional quadriceps tendon repair techniques, adjustable cortical fixation devices are advantageous in that they allow the surgeon to cycle the knee through a full ROM intraoperatively and re-tension the repair when gapping occurs at the tendon rupture site. This ability to retension the construct effectively minimizes the slack in the system that inherently occurs with knee flexion after conventional transosseous or suture anchor repair. Furthermore, the described technique using adjustable cortical fixation produces a "self-tensioning" construct, whereby any gapping that occurs at the repair site postoperatively further tensions the adjustable loop to maintain excellent contact at the tendon—bone interface. This feature of adjustable cortical fixation is unique and may be a means of minimizing the incidence of extensor lag in the postoperative setting.

Adjustable cortical fixation repair also may have the potential to accommodate a more accelerated postoperative rehabilitation protocol by safely allowing patients to begin knee flexion to 90° (or greater) immediately after surgery. Although early ROM and accelerated rehabilitation confer a theoretical benefit of faster return to sport and occupation, a recent meta-analysis showed that early mobilization following surgical repair was associated with greater adverse event rates than late mobilization.[3] These results suggest that there is a clinical need for an alternative technique that can facilitate early mobilization without an increase in adverse events. Although a relatively aggressive ROM protocol was employed successfully in this case series, the utility of accelerated rehabilitation in the context of adjustable cortical fixation repair was not explicitly investigated and represents an important avenue of further research.

The results of this case series suggest that quadriceps tendon repair using adjustable cortical fixation devices is safe at short-term follow-up. A meta-analysis including 709 patients who underwent extensor mechanism repair with conventional techniques reported an adverse event rate of 13% and reoperation rate of 10%,[3] which are comparable with the adverse event rate of 14.3% and reoperation rate of 7.1% reported in the present study. Likewise, the quadriceps tendon re-rupture rate (0%) reported in this study compare favorably to the 5% quadriceps tendon re-rupture rates that have been previously reported in the literature.[4] Further studies that include a greater number of patients followed over a longer period of time are needed in order to determine whether any differences in adverse events or reoperations exist between adjustable cortical fixation repair and the conventional repair techniques.

The clinical outcomes of quadriceps tendon repair with adjustable cortical fixation devices were also satisfactory for most patients. One knee in this case series (7.1%) that underwent delayed operative intervention developed an extensor lag postoperatively. This finding may represent an improvement upon the rate of 20% to 22% extensor lag that has been reported by multiple prior articles examining the conventional repair techniques.[6,9,17] Despite this finding, however, the mean postoperative knee ROM (122.6°) and mean postoperative Lysholm score (86.7) among patients who underwent adjustable cortical fixation repair were slightly lower than the previously reported values for suture anchor repair (mean knee ROM: 127.0°, mean Lysholm score: 91.0) and transosseous repair (mean knee ROM: 132.5°, mean Lysholm score: 92.6).[2] Notably, the patient population in the present study was predominantly composed of sedentary adults with a mean BMI of 33, of whom 12 of 13 individuals (92.3%) were classified as either having overweight or obesity based upon standard BMI cutoffs.[18] Given the established correlation between elevated BMI and decreased knee ROM[19] as well as lower Lysholm scores,[20] it is possible that the inherent characteristics of

our patient population had a substantial effect on these clinical outcomes.

Limitations

Several limitations of the present case series may be identified. From a study design perspective, the main weaknesses are the small sample size, retrospective nature, short-term follow-up, and lack of control group. Prospective cohort studies and randomized controlled trials that compare adjustable cortical fixation repair to the conventional repair techniques would provide higher quality evidence regarding the safety and efficacy of this technique. Our study results obtained in a predominantly overweight, low-demand patient population may not be generalizable to athletic patients, and further investigation is needed to elucidate the return-to-sport outcomes following quadriceps tendon repair with adjustable cortical fixation devices. Functional outcome assessments (eg, quadriceps strength testing, isokinetic evaluation) were not performed in this study.

Conclusions

In this study, adjustable cortical fixation was a safe and effective surgical technique for quadriceps tendon repair, with adequate restoration of quadriceps function and a low rate of adverse events at 2 years' postoperatively.

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