

Outcomes After Repair of Quadriceps Tendon Rupture in Patients Aged 40 Years and Younger

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Background: Injury to the quadriceps tendon is rare and most commonly occurs in middle-aged men. Few reports are available regarding outcomes after quadriceps tendon rupture in younger patients.

Purpose/Hypothesis: To review the clinical outcomes of patients who underwent quadriceps tendon repair at age ≤ 40 years. We hypothesized that this cohort would experience better clinical outcomes in comparison to historical older controls.

Study Design: Case series; Level of evidence, 4.

Methods: Using an institutional database, we retrospectively identified patients who underwent quadriceps tendon repair between January 2009 and December 2017. Patients were included in the study if they were aged ≤ 40 years at the time of surgery and had sustained an isolated, complete tendon rupture. Patient and injury characteristics were recorded. Patients were contacted to complete a custom survey, the 2000 International Knee Documentation Committee (IKDC) form, the Lysholm scale, and the Tegner scale.

Results: Included were 38 patients (86.8% male; mean age, 32.0 ± 6.9 years; age range, 15-40 years), with a mean follow-up of 5.9 ± 2.3 years (range, 2.4-11.3 years). At final follow-up, the mean IKDC score was 74.1 ± 22.6 (range, 26.4-100.0), and the mean Lysholm score was 85.4 ± 20.0 (range, 30-100), which were similar if not inferior to historical controls of patients >40 years. Only 16 patients (42.1%) had unchanged or higher Tegner scores after surgery, whereas 22 patients (57.9%) reported lower postoperative activity level. Overall, 91.2% (31/34) of workers returned at a mean 3.9 months after surgery, whereas 63% (12/19) of athletes were able to return to play at 8.8 months. At final follow-up, 12 patients (31.6%) reported persistent pain and stiffness in their knees. Additionally, 3 patients (7.9%) reported pain without stiffness, and 4 (10.5%) reported stiffness without pain. Patients reporting pain or stiffness had significantly lower IKDC scores, Lysholm scores, postoperative Tegner scores, and change in their Tegner score at final follow-up in comparison to those who did not report pain or stiffness.

Conclusion: Although patients aged ≤ 40 years had satisfactory outcomes after quadriceps tendon repair, this injury resulted in significant long-term sequelae in a substantial percentage of patients, despite their youth. Further, this group did not have better outcomes compared with historical controls aged > 40 years.

Keywords: quadriceps tendon repair; quadriceps tendon rupture; return to play; return to work

Rupture of the quadriceps tendon occurs most frequently in middle-aged males.^{7,11,28} Overall, this is a rare injury, with an incidence hovering around 0.1 in 100,000 in the first 4 decades of life and then climbing to 0.6 in 100,000 between 40 and 69 years of age.⁷ Often, ruptures occur in patients with predisposing risk factors, such as renal dysfunction and diabetes, and have been known to occur bilaterally or in a seemingly spontaneous fashion.^{1,9,13,21,22,30} Less commonly, rupture of the quadriceps tendon has been reported in younger patients (age, <40 years) with a mechanism that

most often involves eccentric quadriceps muscle contraction, forceful knee flexion, or a direct blow to the knee.^{3,27,31}

Numerous studies have shown satisfactory outcomes after quadriceps tendon repair (QTR), although the majority of these studies assessed outcomes in a population that included older and less active patients.^{5,8,24} In fact, a systematic review found the mean age of patients undergoing QTR to be 57 years.⁶ Investigations in patients aged ≤ 40 years are often limited to case reports or small series.^{2,15,16,33} Given the morbidity of quadriceps tendon rupture and the functional goals of younger patients, further investigation into their outcomes is warranted. The purpose of this study was to review the clinical outcomes of patients who underwent QTR at age ≤ 40 years. We

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hypothesized that this patient population would achieve more satisfactory functional outcomes and demonstrate a higher rate of return to their preinjury activity level than would the older cohorts previously investigated.

METHODS

After institutional review board approval was obtained, patients were retrospectively identified via Current Procedural Terminology code in a single institution's database. Patients were included if they underwent primary QTR between January 1, 2009, and December 31, 2017, and were ≤ 40 years of age at the time of surgery. Age 40 years was selected as the cutoff age because previous studies have reported this injury to most commonly occur in patients aged >40 years.^{25,28} Patients were included if they sustained a complete, full-thickness, quadriceps tendon tear, as confirmed via operative notes. Patients with partial tears, bilateral tears, and concomitant injuries, along with those who had received prior surgery to the knee of interest, were excluded. Patients provided informed consent.

Operative and Rehabilitation Protocol

Surgical technique was chosen at the discretion of the primary surgeon and included fixation via transosseous drilling through the patella, suture anchors, or simple sutures. Deep venous thrombosis prophylaxis was not routinely given.

No QTRs were augmented in this cohort. Postoperative protocols were established by the primary surgeon, with all patients undergoing a period of protective weightbearing and bracing with the knee locked in extension followed by progressive weightbearing and knee flexion.

Study Variables

Baseline patient characteristics were collected via chart review, including age at the time of surgery, medical comorbidities, sex, body mass index (BMI), mechanism of injury, and preoperative Tegner score. Time from injury to surgery was recorded, as was operative technique. Injury was considered acute if patients underwent repair surgery within 2 weeks of injury.³² Patients who elected to participate in the study underwent a telephone interview with 1 of 2 authors (S.R. and S.S.), providing postoperative results for the 2000 International Knee Documentation Committee (IKDC) form, the Lysholm knee score, and the Tegner activity scale.^{14,20,29}

In addition, patients completed a custom survey that included preoperative sports participation level (none, recreational, or competitive or professional), work exertion level (not working, mild, moderate, or extreme), ability to return to sports or work at the same level or higher, and the duration of time required to do so. The survey was also used to assess satisfaction (recorded as a percentage), presence of knee stiffness or pain (yes/no response), visual analog scale (VAS) for pain, improvement in function according to the Single Assessment Numeric Evaluation (SANE), and occurrence of complications. Patient charts were reviewed to further identify any postoperative complications during the follow-up period, defined as rerupture, infection, arthrofibrosis, and any other perioperative surgical or medical complication requiring medical treatment, hospitalization, or return to surgery.

Statistical Analysis

Continuous data were reported as means with standard deviations, and categorical data were reported as frequencies with percentages. The distribution of data was assessed using the Shapiro-Wilk test. Continuous data were assessed using the Student *t* test or Mann-Whitney *U* test as appropriate, and categorical data were assessed using chi-square analysis. Subgroup comparisons of postoperative IKDC, Lysholm, and VAS scores were performed according to age (≤ 25 vs 26-40 years), comorbidities (present vs absent), preoperative BMI (≤ 25 vs >25), time to surgery (≤ 7 vs >7 days and ≤ 14 vs >14 days), operative technique (transosseous tunnel vs suture anchors vs simple sutures), and level of return to sport (nonathlete vs athlete, recreational vs competitive/professional) and work (mild/moderate vs extreme). In addition, the association of preoperative Tegner level with postoperative IKDC and Lysholm scores was analyzed using the Spearman correlation coefficient (r_s). For all analyses, the threshold for significance was set at $P < .05$. All statistical analyses were performed using the Statistical Package for the Social Sciences Version 26 (IBM Corp).

RESULTS

Patient, Injury, and Surgical Characteristics

Over the study period, 47 patients aged ≤ 40 years underwent QTR for an isolated rupture. Of these, 38 patients (80.8%) were available for follow-up at a mean 5.9 ± 2.3 years (range, 2.4-11.3 years). A total of 33 patients (86.8%)

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TABLE 1
Preoperative Patient Characteristics and Sports and Work Participation (N = 38)

Variable	Mean ± SD or No. of Patients
Age, y	32.0 ± 6.9
≤25	9
26-40	29
Sex, male/female	33/5
Body mass index	30.9 ± 6.8
≤25	10
>25	28
Predisposing medical comorbidity	6
Preoperative sports participation level	
None	19
Recreational	13
Competitive/professional	6
Preoperative work exertion level	
Not working	4
Mild	10
Moderate	18
Extreme	6

TABLE 2
Summary of Clinical and Patient-Reported Outcomes^a

	Mean ± SD or No. of Patients
Tegner score	
Preoperative	6.3 ± 1.5
Postoperative	4.9 ± 2.0
P value	<.001
Higher postoperative score	2
Unchanged score	14
Lower postoperative score	22
IKDC score	74.1 ± 22.6
Lysholm score	85.4 ± 20.0
VAS pain	1.5 ± 2.0
SANE	82.5 ± 13.9
Satisfaction	88.9 ± 20.6

^aIKDC, International Knee Documentation Committee; SANE, Single Assessment Numeric Evaluation; VAS, visual analog scale.

were male, and the mean age was 32.0 ± 6.9 years (range, 15-40 years) at the time of surgery (Table 1). In total, 6 patients (15.8%) had a medical comorbidity predisposing them to rupture, including rheumatoid arthritis, chronic kidney failure, and hypercholesterolemia. Further, 1 patient had a prior corticosteroid injection to the knee of interest, and another patient reported the use of fluoroquinolones before rupture.

A total of 22 patients (58%) were injured after a low-energy slip, misstep, or fall. A further 12 patients (32%) were injured while participating in a sporting event (1 each injured during football, basketball, baseball, softball, soccer, weightlifting, snowboarding, ice skating, long jump, diving, paintball, and trampoline). As well, 2 patients

TABLE 3
Postoperative Return to Sports Rate, Work Status, and Timing

	No. of Patients (%)	Time to Return, Mean ± SD, mo
Returned to sports	12/19 (63)	8.8 ± 4.6
Recreational	9/13 (69)	9.7 ± 4.9
Competitive/professional	3/6 (50)	6.0 ± 3.0
P	.479	.174
Returned to work	31/34 (91.2)	3.9 ± 3.2
Mild/moderate	26/28 (92.8)	3.5 ± 3.2
Extreme	5/6 (83.3)	5.8 ± 2.7
P	.604	.140

(5%) were injured in a motor vehicle collision, and 2 patients (5%) sustained a traumatic laceration.

We noted that 20 patients (52.6%) had surgery within 14 days of reported injury, whereas only 12 patients (31.6%) in this cohort had surgery within 7 days of reported injury. The median time to surgery was 13 days (range, 0-255 days). A total of 24 patients (63.2%) underwent repair via transosseous tunnels through the patella. A total of 7 patients (18.4%) underwent repair that entailed the use of suture anchors fastened to the superior pole of the patella; 7 patients (18.4%) received simple sutures that secured the proximal tendon to the remaining distal stump of the quadriceps tendon for a primary tendon-tendon repair.

Clinical and Patient-Reported Outcomes

At follow-up, mean IKDC score for the cohort was 74.1 ± 22.6 (range, 26.4-100.0) and mean Lysholm score was 85.4 ± 20.0 (range, 30-100). The median IKDC and Lysholm scores were 82.2 and 95.0, respectively. Postoperative Tegner scores revealed that only 16 patients (42.1%) reported an unchanged or higher activity level at the time of follow-up, whereas 22 patients (57.9%) were at a lower activity level compared with before surgery. In addition, the mean postoperative Tegner score was significantly lower compared with preoperatively (*P* < .001) (Table 3). All postoperative clinical and patient-reported outcomes are shown in Table 2.

Subgroup analyses revealed that the 9 patients aged ≤25 years had significantly higher satisfaction rates than their older counterparts aged 26 to 40 years (*P* = .046) despite having similar postoperative IKDC, Lysholm, and VAS pain scores. No other subgroup analysis demonstrated significant differences in patient-reported outcomes, including analyses of age, presence of comorbidities, preoperative BMI, time to surgery, or operative technique.

Return to Play or Work

A total of 19 patients (50%) participated in sports at the time of surgery, including 5 basketball players, 5 runners, 3 softball players, 2 football players, 1 weightlifter, 1 soccer player, 1 golfer, and 1 cheerleader. We noted that 13 patients played sports recreationally, 3 played sports

TABLE 4
Effect of Pain and Stiffness on Patient-Reported Outcomes^a

	Yes	No	P
Pain	(n = 15)	(n = 23)	
IKDC	54.3 ± 22.2	87.1 ± 10.3	<.001
Lysholm	68.6 ± 21.8	96.3 ± 7.0	<.001
Tegner			
Preoperative	6.3 ± 1.8	6.3 ± 1.4	.946
Postoperative	3.8 ± 2.0	5.6 ± 1.7	.007
Δ	-2.5 ± 2.1	-0.7 ± 1.6	.011
Stiffness	(n = 16)	(n = 22)	
IKDC	61.4 ± 22.3	83.4 ± 18.3	.003
Lysholm	75.0 ± 21.6	93.0 ± 15.1	.008
Tegner			
Preoperative	6.7 ± 1.4	6.0 ± 1.6	.169
Postoperative	4.4 ± 2.1	5.3 ± 1.9	.185
Δ	-2.3 ± 2.2	-0.7 ± 1.7	.021

^aBoldface P values indicate statistically significant difference between groups (P < .05). IKDC, International Knee Documentation Committee.

TABLE 5
Association Between Preoperative Tegner Score and Postoperative Patient-Reported Outcomes^a

	r _s
All patients (N = 38)	
IKDC score	0.088
Lysholm score	0.112
Postoperative Tegner score	0.336
Athletes (n = 19)	
IKDC score	-0.206
Lysholm score	-0.134
Postoperative Tegner score	0.244
Nonathletes (n = 19)	
IKDC score	0.331
Lysholm score	0.388
Postoperative Tegner score	0.444

^ar_s values of -0.5 to -0.3 indicate a weak negative relationship, -0.3 to 0.3 indicate no true relationship, and 0.3 to 0.5 indicate a weak positive relationship. IKDC, International Knee Documentation Committee.

competitively in high school or college, and 3 competed professionally (Table 1). At final follow-up, 12 patients (63.2%) reported returning to play at the same or higher level at a mean of 8.8 ± 4.6 months after surgery. All 7 patients who were unable to return to play cited injury-related issues as the cause. When comparing competitive athletes with recreational athletes and athletes with nonathletes, we observed no differences in patient-reported outcomes, rate of return to play, or time to return to play (Table 3).

A total of 34 patients (89.5%) were employed at the time of their injury; 10 patients described the physical demand of their preinjury occupation as mild, 18 described it as moderate, and 6 described it as extreme. Overall, 31 patients (91.2%) were able to return to work at the same

TABLE 6
Comparison of Current Study Results (Patients ≤40 Years of Age) With Published Data for Patients >40 Years of Age^a

Study (Year)	Sample Size, n	Mean Age, y	Follow-up, mo	Lysholm	IKDC	Tegner
Current study	38	32.0	70.8	85.4	74.1	4.9
Konrath et al ¹⁷ (1998)	39	56	48	86	—	2.6
Ellanti et al ⁸ (2016)	6	81.4	54	84.8	—	—
Wenzl et al ³² (2004)	35	55	55	92.5	—	—
Boudissa et al ⁴ (2014)	50			knees	55.4	76
93.7	—	3.4				
Plesser et al ²⁴ (2018)	SA, 9 TS, 8	SA, 62.7 TS,	57.9	SA, 46 TS, 29	SA, 88 TS, 94	SA, 76.0 TS, 85.1
Mille et al ²³ (2016)	11	65.8	14.7	—	—	2.8

^aDashes indicate data not provided. IKDC, International Knee Documentation Committee; SA, suture anchor; TS, transosseous tunnel.

or higher level at a mean 3.9 ± 3.2 months from surgery (Table 3). We noted that 3 patients (8.8%) did not return to work because of persistent pain, swelling, and/or instability. Those who reported having mild/moderate physical work demands returned to work at a similar rate to that

TABLE 7
Comparison of Current Study Results (Patients ≤ 40 Years of Age) With Published Data for Patients >40 Years^a

Study (Year)	Sample Size, n	Mean Age, y	Follow-up, mo	Lysholm	IKDC	Tegner
Current study	38	32.0	70.8	85.4	74.1	4.9
Konrath et al ¹⁷ (1998)	39	56	48	86	—	2.6
Ellanti et al ⁸ (2016)	6	81.4	54	84.8	—	—
Wenzl et al ³² (2004)	35	55	55	92.5	—	—
Boudissa et al ⁴ (2014)	50 knees	55.4	76	93.7	—	3.4
Plessner et al ²⁴ (2018)	SA, 9 TS, 8	SA, 62.7 TS, 57.9	SA, 46 TS, 29	SA, 88 TS, 94	SA, 76.0 TS, 85.1	SA, 4 TS, 5
Mille et al ²³ (2016)	11	65.8	14.7	—	—	2.8

^aDashes indicate data not provided. IKDC, International Knee Documentation Committee; SA, suture anchor; TS, transosseous tunnel.

of those who reported having extreme physical demands ($P = .604$). Further, they returned to work after a similar duration ($P = .140$).

Postoperative Pain and Stiffness

At the final follow-up, 12 patients (31.6%) reported persistent pain and stiffness in their knee. Additionally, 3 patients (7.9%) reported pain without stiffness, and 4 (10.5%) reported stiffness without pain. Patients reporting pain had significantly lower IKDC scores ($P < .001$), Lysholm scores ($P < .001$), postoperative Tegner scores ($P = .007$), and change in Tegner score ($P = .011$) at final follow-up. Similarly, patients reporting stiffness had significantly worse IKDC scores ($P = .003$), Lysholm scores ($P = .008$), and change in Tegner scores ($P = .021$) compared with those who did not report stiffness (Table 4).

Association of Preoperative Activity Level With Postoperative Outcome Scores

Preoperative activity level by Tegner score did not correlate with postoperative IKDC or Lysholm scores but did positively correlate with postoperative Tegner score ($r_S = 0.336$). When considering athletic participation, we found that this positive correlation was stronger in the nonathlete subgroup ($r_S = 0.444$) (Table 5).

Complications

The overall complication rate was 5.3%, with quadriceps tendon rerupture occurring in 1 patient at 8 months after initial repair. Another patient experienced a pulmonary embolism 6 days postoperatively that resolved with use of oral anticoagulant drugs. A total of 5 patients (13.2%) reported numbness over the anterior knee, and 3 patients (7.9%) reported clicking or popping. We noted that 2 patients sustained injuries to their contralateral knee during the follow-up period; 1 patient ruptured his quadriceps tendon, and the other ruptured his anterior cruciate ligament. No wound infections were reported.

DISCUSSION

The principal findings of this study show that patients had satisfactory outcomes overall, as demonstrated by patient satisfaction and VAS, IKDC, and Lysholm scores. However, our findings also highlight that quadriceps tendon rupture is more devastating to this age group than one would expect and has lasting consequences. This is evident by the number of patients who were unable to return to work or sport as well as the large proportion of patients with continued deficits, exhibited by Tegner scores and patient-reported pain and stiffness.

Rupture of the quadriceps tendon most commonly occurs in middle-aged and older patients.¹¹ In numerous studies, QTR has been shown to yield acceptable outcomes in this population.^{4,5,8,17,23,24} Several studies on patients aged >40 years that used the same outcome measures reported here have been performed, allowing us to make comparisons with our cohort (Table 6).^{4,8,17,23,24,32}

Konrath et al¹⁷ reported on a cohort of 39 patients with a mean age of 56 years and found the mean Lysholm score to be 86 at 4 years after surgery, which is similar to the mean Lysholm score reported in our cohort (Table 7). These results align with those reported in smaller case series, such as that by Ellanti et al.⁸ In contrast, despite investigating older cohorts, others have reported better Lysholm scores than those seen in our cohort. Wenzl et al³² reported on 35 patients with a mean age of 55 years and found a mean Lysholm score of 92.5 at 55 months. Boudissa et al⁴ reported a Lysholm score of 93.7 at 76 months in 50 knees in patients with a mean age of 55.4 years. With respect to Lysholm scores, our data indicated that patients ≤ 40 years have similar if not inferior outcomes to those of their older counterparts. The lower outcome scores in our cohort may reflect higher demands placed on the repaired knee and higher expectations by patients that they would return to normal.

Only 1 prior study to our knowledge has reported on IKDC. The mean IKDC score of 74.1 that we found is comparable to the score of 76.0 reported by Plessner et al²⁴ in their suture anchor group ($n = 9$) and inferior to the score of 85.1 reported in their transosseous tunnel group ($n = 8$);

however, the small cohorts investigated by Plessner et al make comparison challenging.

Several comparisons regarding activity in our cohort of patients aged ≤ 40 years can be made, as measured via the Tegner scale. Overall, our cohort demonstrated a significant decrease between preoperative and postoperative Tegner scores (from 6.3 to 4.9; $P < .001$). Konrath et al¹⁷ similarly reported a significant decrease in Tegner score from a preoperative score of 3.7 to a score of 2.6 at 4 years. Boudissa et al⁴ reported a mean Tegner score of 3.4 at 76 months of follow-up, whereas Mille et al²³ reported a score of 2.8 at 14.7 months of follow-up in 11 patients with a mean age of 65.8 years. In a 17-patient cohort with a mean age of 62.7 years in the suture anchor group and 57.9 years in the transosseous group, Plessner et al²⁴ reported Tegner scores of 4 and 5, respectively, a relative higher outlier compared with the other studies. Despite having higher overall activity scores, as expected in comparison to older cohorts, our patient population still experienced a lasting reduction in activity level from their preoperative level. Although, in part, this decrease may reflect age-related changes in activity as our population aged during the follow-up period, the reduction in activity level is likely due to persistent pain and weakness when taken with the rest of the results.

Prior studies have analyzed the effect of prompt surgical intervention as well as surgical technique.^{25,26,28,32} These investigations indicated that those patients who undergo delayed repairs experience worse outcomes. In our cohort, when stratified by time to surgery, patients who had surgery within 7 days and those who had surgery within 14 days did not report better outcomes than did those who had longer delays to surgical intervention. Prior studies have concluded that surgical technique does not have a significant effect on functional outcomes.^{24-26,32} Our results further support those findings, given that when we compared those patients who underwent fixation via transosseous drilling, suture anchors, or simple suture techniques, we found no differences in patient-reported outcomes.

Due in large part to the youthful and active nature of our population, we were able to report a return to play rate of 63% in 19 athletes of varying degrees of competitive involvement. Return to play after QTR is rarely discussed in the literature and is often only reported in case reports.^{10,12,19,33} In one example, Zuke et al³³ reported a case of a young baseball player who was able to fully return to sport at 1 year with an IKDC score of 93.1. Boublik et al³ reported a return to play rate of 50% in 14 professional football players after QTR. Mille et al²³ reported all 11 of their patients returned to play at an average of 4.5 months. To our knowledge, our reported return to play rate of 63% at a mean of 8.8 months appears to be the first figure of its kind that includes classification between 20 competitive/professional and recreational athletes. Similarly, our reported return to work rate of 91.2% at a mean of 4 months after surgery seems to be in accordance with most reported rates observed in the literature (range, 84%-100%).^{4,5,17}

Our rate of 1 rerupture in 38 patients (2.6%) is similar to the findings of other studies, several of which have reported no reruptures.^{4,32} Conversely, Mille et al²³ reported that 2 of 11 patients (18.2%) experienced rerupture. It might be

expected that outcomes after QTR would be more favorable in a younger, active population than in an older population, as younger patients may have greater rehabilitation potential. Our results do not support this, however, as our patients had relatively low patient-reported outcomes. It is unclear whether this finding is due to the demands placed on a surgically repaired knee in younger patients, the patients' unmet expectations that they would "return to normal" because of their younger age, or simply the fact that this injury is more debilitating across all age groups than one would expect.

Strengths and Limitations

The strengths of this study include our sample size for a rarely captured population and our focus on both patient-reported outcomes and activities. This study, however, was not without limitations. This was a retrospective investigation. We did not have any preoperative patient-reported outcomes other than Tegner activity level, and we relied on the patients to recall their preoperative status. The surveys were conducted via telephone interview, which inherently may produce more biased results compared with those administered in clinic. Our study population consisted mostly of male patients, which is consistent with descriptive data presented in previous studies, but this may preclude our results from being accurately extrapolated to the general female population. Additionally, our study lacked a control group; instead, we decided to focus on previous investigations to make comparisons. Because of the inconsistency of the medical records, we decided not to report a postoperative range of motion, and we did not directly perform strength or functional testing. This investigation also used an institutional database of multiple orthopaedic surgeons with different repair and rehabilitation protocols, which introduced potential bias into our investigation. Although we analyzed the effect of the operative technique on our primary outcomes, we were unable to analyze the effect of rehabilitation protocol because of inconsistencies in the electronic medical records. However, prior studies have compared various rehabilitation protocols and found no difference in patient-reported outcomes.^{18,26}

CONCLUSION

Although patients ≤ 40 years of age had satisfactory outcomes after QTR, this injury results in significant long-term sequelae in a substantial percentage of patients, despite their youth. Further, this group did not have better outcomes compared with historical controls aged >40 years.

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