

Use of Quadriceps Tendon and Bone Plug for Anterior Cruciate Ligament Reconstruction: Experience using a V-Blade and Tube Knife.

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Abstract

The quadriceps tendon graft is a well-reported but rarely used option for ACL reconstruction. The “tendon only” and “tendon with bone plug” versions of this graft have both been thoroughly studied but neither have been adopted by mainstream Orthopaedic surgeons. Research indicates that this graft is at least equivalent and possibly superior in many respects when compared to traditional



V-Blade, Quad Tendon Graft with Attached Bone Plug, Tube Knife

graft options (patellar tendon, hamstring tendon, and allograft). This case series describes the preferred technique developed by four separate orthopaedic surgeons who converted to the quadriceps tendon graft when given a specialized v-blade and tube knife. Eighty-nine (89) patients underwent ACL reconstruction utilizing the quadriceps tendon autograft. A retrospective review was done to examine the preferred technical methods chosen and results observed. There was one traumatic graft failure three years postoperatively (1%). There was one endo-button failure early in rehab and this patient was lost to follow up. There was zero incidence of anterior knee pain long

20 term. Typical quad atrophy was generally 1 cm at four months, and at one year generally was
21 resolved. Pain scores were dramatically lower, especially in those patients with no other meniscal,
22 ligamentous, or cartilage damage. These results reflect the historical benefits of the Quadriceps
23 Tendon graft, with the additional improvements of simplified fixation and ease of use. Quadriceps
24 graft utilization with these instruments increased from 0 to 77%. Widespread adoption of this
25 technique will improve the standard of care worldwide.

26 Introduction

27 ACL tears are one of the most common knee injuries. It is a devastating event and left untreated will
28 result in permanent knee instability. Approximately 200,000 Anterior Cruciate Ligament (ACL) tears
29 occur annually in US^{1,2} and more than one million ACL tears occur worldwide per year.³ While the

30 Quadriceps Tendon Autograft has been studied for
31 over thirty years and has consistently yielded lower
32 postoperative pain scores than other autograft
33 techniques, it still accounts for less than 2 percent of
34 all ACL reconstructions.^{5,6,7,8,9,10,11,12,13,14,15,16} The

35 historically reported techniques are essentially free-
36 hand methods that are difficult to do and hard to
37 reproduce. The procedure is unfamiliar and complicated
38 by many technical difficulties. Studies have shown
39 similar outcomes both when the quad tendon is taken
40 as a soft tissue graft only and when it is taken with a
41 patellar bone plug.^{Shelton article,} The easier of the two
42 harvesting methods involves taking a soft tissue only
43 graft with a rectangular cross section. However the
44 lack of a bone plug on this graft leaves it shorter and
45 thus complicates fixation. This usually necessitates hand

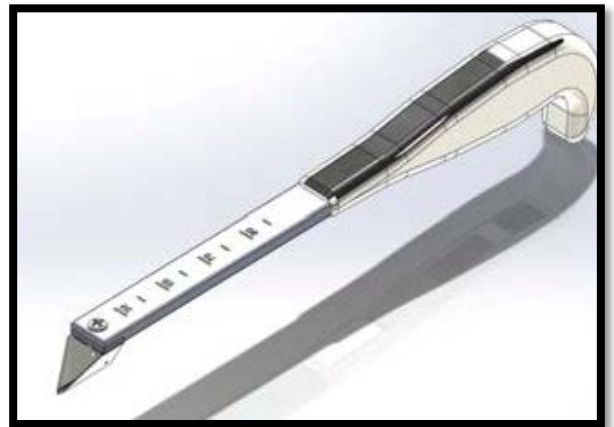


Figure 1 – V-Blade with Handle

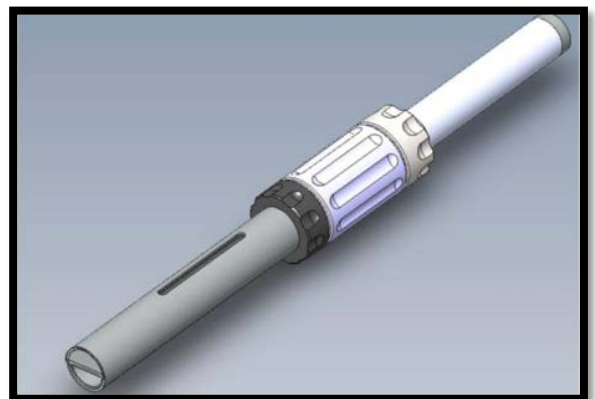


Figure 2 – Tube Knife

46 tying non-looped endobuttons on the femoral side, creating another technical challenge that many
47 surgeons do not choose to tackle. These difficulties likely explain the historically limited use of the
48 Quad Tendon Graft for ACL reconstructions, in spite of the superior outcomes that have been
49 reported in the literature.

50 **Methods**

51 **Study Group**

52 This case series is a retrospective review of 89 patients undergoing ACL reconstruction by four
53 separate surgeons utilizing a quadriceps tendon graft. In 2014 a blade system was made available to
54 them for the purposes of simplifying quad tendon graft harvesting. Some general guidelines for use
55 were given but surgeons were free to harvest and secure the graft with whatever methods they felt
56 appropriate. Prior to this study, none of the surgeons were using the quadriceps tendon as a graft
57 source. The general surgical technique is summarized below, with each surgeon modifying it to their
58 liking. This retrospective literature review was exempt from IRB review. Of particular interest, the
59 forms of fixations, failure rates, complication rates, and general patient outcomes were reviewed.

60 **Surgeon Demographics**

61 Four main surgeons completed the bulk of the cases. The ages of the surgeons were (52,49,52, and
62 60- average age 53.25). All four are board certified in Orthopaedic surgery. Two have subspecialty
63 certification in sports medicine and one completed a six-month sports fellowship and one completed
64 a AAOS travelling trauma fellowship. The author is board certified in Orthopaedic Surgery with a
65 specialization in knee procedures, mainly arthroplasty. Other than the author, none of the surgeons
66 has any financial connections to the manufacturer of the blade set. Prior to this study, none of the
67 surgeons had ever used the quadriceps tendon for ACL reconstruction.

68 **General Description of Surgical Technique (with and without bone plug)**

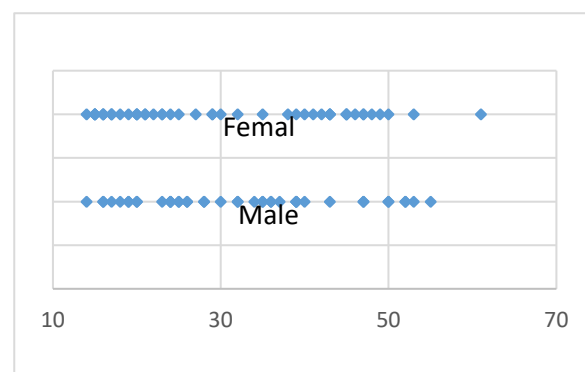
69 A transverse or longitudinal skin incision is made over the proximal third of the patella. Bursal tissue
 70 is removed. When a bone plug is desired, the knee is placed in extension while the bone cuts are
 71 made using a standard ACL saw and saw blade (center of patella). A suture is then placed through
 72 either the bone plug or the soft tissue end of the graft (when not using a bone plug). While pulling
 73 on the suture to tension the tissue, parallel cuts are made on the top of the tendon proximally,
 74 stopping before the musculo-tendinous junction. The suture is then passed through the v-blade,
 75 which is then passed over the proximal bone plug or tendon stump and up the tendon, thus creating
 76 the graft. A tube knife is used to amputate the proximal soft tissue end without having to make a
 77 second incision or extend the original incision. Tunnel placement and graft fixation are performed by
 78 physician preference. Physical therapy was achieved using a specific protocol designed for this
 79 technique.

80 **Results**

Figure 3- Patient Demographics

81 Patient Demographics

82 There were 89 patients with an age range from 14
 83 to 61 years. The mean patient age was **31.5 years**
 84 with a median age of **29 years** and a standard
 85 deviation of 12.6 years. There were 48 females and
 86 41 males. There were twice as many female tears



87 under age 20 (twelve females, six males). Twelve of these cases were revisions, with three being
 88 second revisions, none of which had the quadriceps tendon as the original reconstruction. There
 89 were more than twice as many revisions in male patients than females (ten versus four). Four
 90 patients had already sustained an ACL tear on their contralateral knee and undergone
 91 reconstruction there.

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Figure 4 – Preferred Femoral Fixation



Biocomposite Fixation with Bioabsorbable Interference Screws in Femur and Tibia

Figure 5 – Endobutton Fixation Femoral Side



Endobutton Fixation with Bioabsorbable Interference Screw fixation in Tibia +/- Push lock anchor

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103 Femoral Fixation:

104 All surgeons were strongly in favor of using the bone plug version of the graft and they all preferred

105 to use bone plug fixation (usually interference screw fixation) on the femoral side. Early in the

106 series, the bone/graft interface was damaged when the saw cuts were made with the knee in

107 flexion, preventing the bone plug from being used on the femoral side thus requiring the use of a

108 soft tissue-endobutton option for femoral fixation. **Nineteen (19.1%)** patients ultimately underwent

109 endobutton type fixation on the femoral side. Extending the knee while taking the bone plug

110 prevented the saw blade from damaging the graft, and resulted in a more pristine bone/tendon

111 interface. After this technical change, femoral fixation was performed almost exclusively with the

112 bone plug in the femoral tunnel. **Seventy two (80.9%)** patients underwent interference screw

113 fixation the femoral end. The vast majority of these we of a bio-composite with a smaller number of

114 titanium interference screws. Notably, the triangular cross section of the bone plugs fills more of
115 the femoral tunnel than the Patellar Tendon BTB trapezoidal bone plug. Surgeons should be
116 prepared to start with the smallest femoral tap due to this. In a few cases with a posterior wall blow
117 out negating the use of an interference screw, an endo-button was used, usually with again the bone
118 plug on the femoral side. Additionally we used soft tissue with an endo-button on the femoral side
119 in two patients who were approaching skeletal maturity. Studies show that the first growth plate
120 closure in the knee occurs in the central area of the tibial physis. Due to this, we inverted the graft
121 and used an endo-button on the femoral side to prevent premature closure here, although the
122 amount of growth left in these patients was negligible.

123 Tibial fixation.

124 The quality of the bone usually determined the method. **Fifty-two patients (58.4%)** underwent tibial
125 fixation with an interference screw only on the tibial side, with every graft prepared with a Krakow
126 suture pattern in this “soft tissue end” of the graft. **Thirty patients (33.7%)** had an interference
127 screw backed up with a push/swivel lock using the Krakow suture ends. **Six patients (6.7%)**
128 underwent interference screw fixation backed up with a post and washer, and these were patients
129 with additional ligamentous injuries. One patient (**1.1 %**) had an interference screw with a soft
130 tissue staple for additional security. All of the fixation options used in this series on both sides are
131 commonly used with other types of ACL reconstruction.



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Figure 7 – Tibial Fixation with
Interference screw, post and washer

Graft Tensioning was done in an identical manner as a bone-patellar tendon-bone autograft. The Quad Tendon has mechanical properties similar to a patellar tendon autograft, and should have fixation at a

138 similar tension as a patellar tendon autograft. Tensioning the graft at 30 degrees of flexion, as is
 139 done with a hamstring, will over-tension the graft. Typical fixation on the tibial side is an
 140 interference screw +/- a swivel lock. (use reference)

141 Complications:

142 There were no infections in any of the procedures. There were
 143 no deaths or major disabilities resulting from any of the cases.
 144 There was one graft failure at three years postop in a high-energy
 145 water-skiing accident. There was one fixation failure that was lost
 146 to follow-up. No other graft failures were reported. There were



Figure 8- Endo-button Failure

147 no quadriceps ruptures or partial tears. Anterior knee
 148 pain was essentially nonexistent, even within the first
 149 few months after surgery. No patient required
 150 manipulation.

151 There was one endo-button failure noted on the
 152 first post-op visit after an incident in physical therapy.

153 This patient was lost to follow-up.

154 There were two patella fractures. One occurred
 155 **two weeks post op** when he fell while jumping on a

156 trampoline. One occurred eight weeks post-op after a fall running in the rain. These were vertically
 157 oriented fractures. ORIF with transverse screws achieved successful union. Arguably these were
 158 preventable.

159 Quadriceps atrophy was less than would be anticipated. Most patients by month four had
 160 recovered most of their mass and has a 1 cm side to side difference 15 cm proximal to the patella.



Figure 9- ORIF Patella Fracture in Immediate Post-op Period

161 Older patients tended to have more atrophy, and some young patients (especially cyclists) had
 162 identical side to side measurements at four months.

163 The joint space was violated in many of the cases, however no morbidity was noted. Some of
 164 these defect were closed at surgery, and many were left open. There were no postoperative cues to
 165 identify who did or did not have a joint space defect, nor if they had it closed or left open.

166 There was generally a bimodal distribution of narcotic usage. Patients with isolated ACL
 167 reconstruction without meniscal debridement or repair, or concomitant MCL injury, required less
 168 than one week of narcotics, and usually three days was the reported average. A second pathology
 169 increased the narcotic usage more than would be expected.

170 Three cases were done in arthritic patients to restore the ACL in preparation for a future partial
 171 knee replacement. Two of these reported less pain
 172 after restoring stability to the knee, and to date have
 173 avoided arthroplasty. One was found to have lateral
 174 disease and has since had total knee replacement.

	Pre Instruments				Post Instruments			
	ham	BTB	Allog	Quad	ham	BTB	allog	Quad
Surgeon 1	0	80	20	0	0	0	10	90
Surgeon 2	0	80	20	0	0	45	10	45
Surgeon 3	0	80	20	0	0	0	5	95
Surgeon 4	50	20	30	0	5	5	10	80
Average	12.5	65	22.5	0	1.25	12.5	8.75	77.5

Figure 10- Self Reported Graft Utilization With and Without Quad Tendon Blade Set Increased from **0 to 77.5%**

175 Prior to this study, none of the surgeons were
 176 using the quadriceps tendon for ACL Reconstruction.

177 After introducing the instruments, the surgeons chose the quad tendon graft with a bone plug 77.5
 178 % of the time.

179 **Discussion**

180 Based on the results in the literature, the Quadriceps Tendon should be a top choice as a
 181 graft source for ACL reconstruction. The lower short- and long- term morbidity and the excellent
 182 functional results are well documented. Its negligible use therefore must be attributed to technical
 183 difficulties in performing the procedure. Interest has increased recently, possibly due to refinement
 184 of other ACL techniques such as the “all inside” ACL reconstruction, which also utilizes endo-button

185 fixation more prominently. However, use of the quadriceps tendon is still limited to surgeons who
186 are highly specialized in ACL reconstruction in just a few institutions. This study is the first of its kind
187 to introduce the quadriceps tendon / bone plug option to a group of general orthopaedic surgeons
188 and to examine their preferred surgical techniques when multiple options are given.

189 All surgeons preferred the bone plug and strongly preferred fixation of the bone plug on the
190 femoral end. This required an alteration of the patient positioning when taking the bone plug. Most
191 graft harvests are done with the knee in flexion, however this resulted in damage to the
192 bone/tendon interface when the saw was used to cut the bone plug. Placing the knee in extension
193 solved this problem. **Endo-buttons were only utilized in cases when an interference screw was not**
194 **feasible.** Notably with the quad tendon graft, the endo-button is not a looped construct, and Krakow
195 suture weaves are hand tied to the endo-button, in the manner described by Fulkerson.

196 The surgeons all maximized the graft length on every harvest. A maximal graft length was
197 always desired, not limiting the length of the graft in any way- with many grafts up to 100 mm in
198 length. All cases were done with standard tibial and femoral tunnels, with no all-inside procedures
199 being performed.

200 Historical generalizations of the quad tendon graft
201 emphasize the difficulty in obtaining the graft and the tendency
202 to violate the joint, but also note the lower pain scores
203 postoperatively and the lack of anterior knee pain. Based on the
204 results of this group of patients, it can be confirmed that
205 use of the quad tendon graft results in dramatically less
206 postoperative pain, less anterior knee pain (essentially
207 zero), and easier rehabilitation. The historical concern
208 about violating the joint space has proven to be clinically insignificant. The difficulty in obtaining the
209 bone plug was also confirmed but changes to the technique alleviated this problem.



Figure 11 – Imperfect Depth Measurement with Patellar Bone Plug Harvest

210 The one complication that WAS seen and is shared with patellar tendon BTB was patella
211 fracture (two patients). Patella fracture is a common complication with Bone-tendon-bone
212 autograft patients, as any procedure that involved a bone plug will temporarily weaken the bone. It
213 is notable that the two that were seen in this series were due to mishaps early in the postoperative
214 period. One was a patient who was on a trampoline two weeks post op, and the other was running
215 in the rain without her brace on at around the 8 week mark. She was a small gymnast and had a
216 smaller patella. These events were potentially avoidable and could also happen with standard
217 patellar tendon BTB harvests. Additionally, cutting guides have been developed (since the
218 completion of the study) to give more control over the bone plug harvest. Marking the saw blade
219 at the appropriate depth to prevent plunging will also lower the risk of patella fracture.



Figure 12 – Patellar Bone Plug cutting Guide



Figure 13 – Controlled width and angulation with Bone Cutting Guide

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221 The diminished pain with Quad Tendon ACL reconstructions requires that the surgeon and
222 therapists emphasize the rehab protocols. **“Let pain be your guide” is not a good rule to follow** in
223 the rehab period because pain scores will drop before a patient will have adequate graft
224 incorporation and donor site recovery. While patient compliance is important, this lower pain
225 level is a refreshing problem to encounter. While we did not concentrate on tabulating morphine
226 equivalents taken in the post-operative period, most patients only required narcotics for a few days,

227 with published results reporting an average of three days of narcotic use for uncomplicated ACL
228 reconstructions with quadriceps tendon autografts. Our experience parallels these results.

229 In Summary, the quadriceps tendon is an excellent graft source and should be a viable
230 choice for all surgeons. The historically described techniques have been well known for decades but
231 have had negligible use due to the technical difficulties involved. In this short series, the quadriceps
232 tendon graft was used with a bone plug, and became the graft of choice for surgeons in **77.5** percent
233 of patients having an ACL reconstruction. Interestingly the incorporation of the bone plug in the
234 graft allowed for the surgeons to use the fixation methods they were already familiar with. The
235 addition of the bone plug to the graft combined with the instruments to simplify its harvest will
236 increase its use, and, as in this series, may become the preferred graft choice for many surgeons.
237 The introduction of the cutting guide should also further simplify the technique and improve patient
238 outcomes. The lack of long-term complications should result in improved “return to sport” outcomes
239 when compared to other graft options. Further prospective studies are warranted.

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