



# Application of a Beta-Tricalcium Phosphate Graft to Minimize Bony Defect in Bone–Patella Tendon–Bone Anterior Cruciate Ligament Reconstruction

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**Abstract:** Anterior cruciate ligament (ACL) reconstruction with a bone–patellar tendon–bone autograft yields good clinical outcomes. Despite appropriate clinical outcomes, the most common complaint after reconstruction with a bone–patellar tendon–bone autograft is anterior knee pain at the donor graft sites. Synthetic bone grafts, such as beta-tricalcium phosphate ( $\beta$ -TCP), have been previously used to fill the bony defect in fractures as well as removal of bony tumors, and have shown positive utility in improving anterior knee pain after ACL reconstruction. In this Technical Note, we describe the technique of placing a  $\beta$ -TCP graft in the donor graft site after bone–patellar tendon–bone ACL reconstruction. After standard arthroscopic ACL reconstruction, the  $\beta$ -TCP is appropriately sized with an osteotome and sagittal saw before being placed into the patellar and tibial donor sites. A 0-Vicryl suture is used to suture the periosteum to secure the  $\beta$ -TCP graft at the donor sites. This described technique allows for appropriate sizing and secure placement of the graft to maximize bone regeneration at the donor site.

**A**nterior cruciate ligament (ACL) tears are one of the most prevalent traumatic knee injuries amongst athletes, occurring in nearly 69 cases per 100,000 person-years,<sup>1</sup> and is most commonly managed with operative reconstruction to regain previous mobility. Use of the middle third of the patellar tendon is the most common autograft resulting in good clinical outcomes, and is often the first choice for young athletes.<sup>2,3</sup> However, patients treated with bone–patellar tendon–bone autografts have frequent

complaints of long-term postoperative anterior knee pain and pain while kneeling.<sup>3-5</sup>

Without bone grafting at bone–patellar tendon–bone harvest sites, there is no evidence of bone regeneration, even at long-term time points.<sup>6</sup> It has been hypothesized that anterior knee pain in bone–patellar tendon–bone autografts occurs because of the bony defect at the donor site or as a result of infrapatellar nerve damage during harvest of the tendon.<sup>7</sup> In an effort to reduce anterior knee pain experienced in patients with bone–patellar tendon–bone autografts, surgeons may elect to use hamstring autografts despite evidence that hamstring autografts are associated with graft loosening and knee flexion weakness.<sup>8</sup>

Bone grafts have been used previously in reconstructive orthopaedic surgery to assist in bone realignment and stable fixation in malunion or nonunion fractures.<sup>9</sup> Refilling the donor sites in ACL reconstruction with autologous bone obtained from coring the femoral and tibial sockets reduces the incidence of anterior knee pain<sup>10</sup>; however, this technique does not yield a sufficient amount of bone graft to fill the donor sites. Harvesting bone from other donor sites, such as the iliac crest, may provide sufficient amount of bone, but it is associated with donor site morbidity.<sup>10,11</sup> Synthetic materials, such as beta tri-calcium

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*The author reports the following potential conflicts of interest or sources of funding: B.F. receives personal fee from Elsevier, Arthrex, Jace Medical, and Styker; and grants from Smith & Nephew and Ossur. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).*

*Received February 6, 2018; accepted March 8, 2018.*

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*2212-6287/18181*

*<https://doi.org/10.1016/j.eats.2018.03.009>*



**Fig 1.** Right knee in 10° of flexion. Gross image of the distal insertion of the patellar tendon into the tibial tubercle. An osteotome is used to remove the bone blocks for the bone–patellar tendon–bone autograft that is to be used in the anterior cruciate ligament reconstruction portion of the procedure.

phosphate ( $\beta$ -TCP), possess osteoconductive properties to facilitate bone regeneration, and do not incur the risks of donor site morbidity as evidenced with cancellous autografts.<sup>12</sup>  $\beta$ -TCP grafts allow for early resorption by osteoclasts and osteoblastic cell attachment to the junction of the graft surface and bone, allowing for new bone formation and direct attachment between the graft and the native bony tissue.<sup>13</sup>

$\beta$ -TCP grafts have been investigated histologically and through imaging modalities, but the technique of implementing the graft during ACL reconstruction has yet to be described.<sup>13-16</sup> The aim of this Technical Note is to illustrate the application of a  $\beta$ -TCP graft after an ACL reconstruction for bone regeneration at autograft donor sites.

### Technique

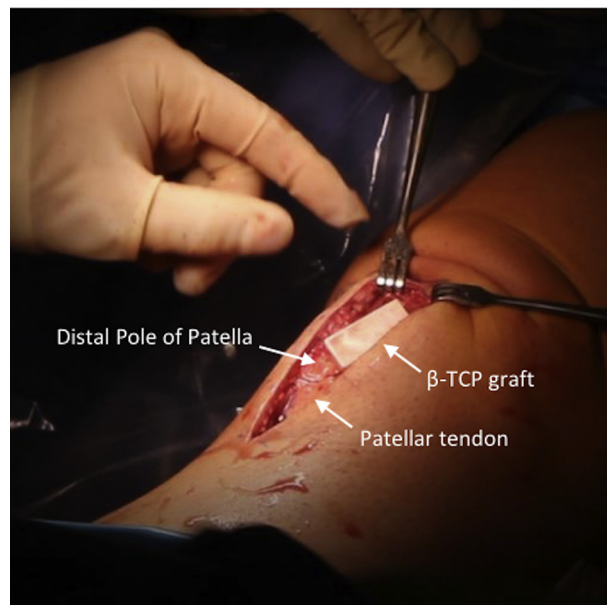
After confirming rupture of the ACL by magnetic resonance imaging and examination under anesthesia, a single bundle ACL reconstruction is employed. A short, vertical midline incision is made from the inferior pole of the patella to the tibial tubercle. Medial and lateral soft tissue flaps are developed, and the paratenon is then incised in line with the skin incision to expose the patellar tendon. Rectangular-shaped patella and tibial bone blocks are then harvested with the use of a sagittal saw and a curved osteotome (Fig 1), measuring 20 to 25 mm and 30–35 mm in length, respectively. Each bone block should measure approximately 10 mm in width and 10 mm in depth.

After standard ACL reconstruction of the graft, the knee remains in 10° of flexion, and the patellar and

tibial donor graft sites are measured. As demonstrated in Video 1, wedges of a 10-mm-thick  $\beta$ -TCP graft (Osferion; Arthrex, Naples, FL) can be initially placed within the bony defects to approximate how much graft must be removed for a proper fit (Fig 2). The  $\beta$ -TCP is then cut with a sagittal saw for appropriate sizing within the bony defect (Video 1 and Fig 3). Cancellous bone that was collected from the tibia and femoral tunnels can be placed along the base of the defect creating a flat surface for the graft to rest upon. After appropriate sizing of the  $\beta$ -TCP graft, it is placed into the bony deficit. As depicted in Video 1, the graft is gently tamped into position for a press fit with an impactor and mallet (Fig 4). After placement of the  $\beta$ -TCP graft, the remaining cancellous bone from the bony tunnels can be placed on top of the graft. The periosteum is then closed over the top of the graft with a 0-Vicryl absorbable suture (Video 1 and Fig 5). The described process is repeated for the tibial donor site. After fixation of the graft, the paratenon (Fig 6), subcutaneous tissue, and dermis are closed in a standard fashion. After operative repair, the patient is then immobilized with a knee brace and can be discharged home the same day. Common pearls and pitfalls of applying a  $\beta$ -TCP graft are described in Table 1.

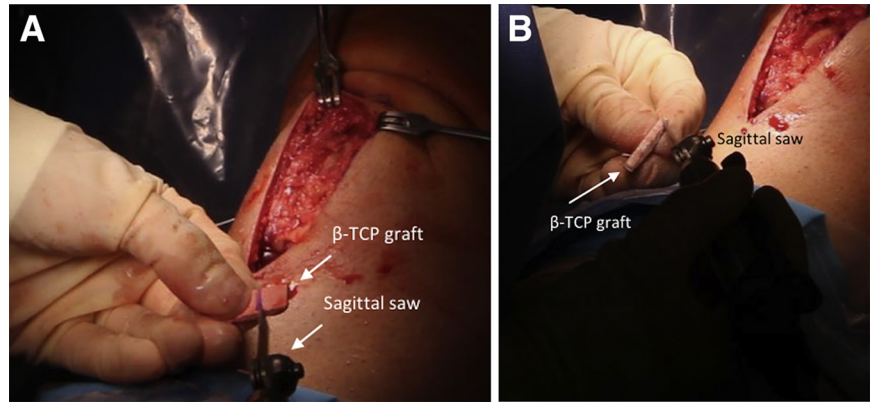
### Discussion

Bone–patellar tendon–bone autografts remain the most commonly used autograft in ACL reconstruction, especially in young athletes.<sup>2,3</sup> Outcomes after



**Fig 2.** Right knee in 10° of flexion. Gross image of the proximal insertion of the patellar tendon into the distal pole of the patella. An unshaped wedge of 10-mm-thick beta-tricalcium phosphate ( $\beta$ -TCP) is placed within the bony defect to approximate the amount of graft that must be removed to allow for a proper fit.

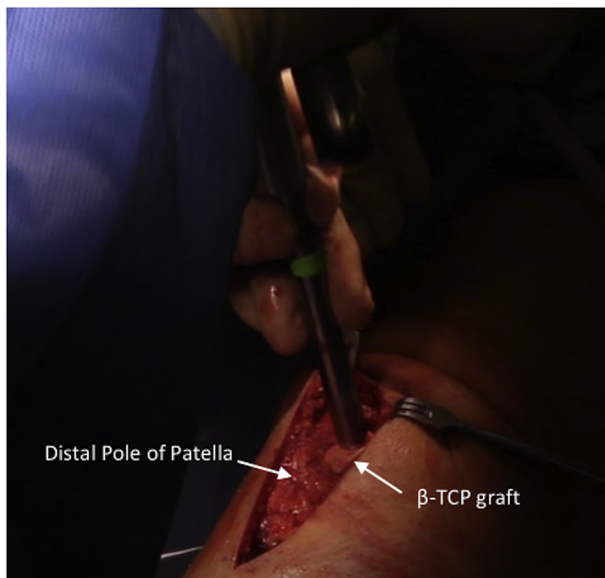
**Fig 3.** (A) Right knee in 10° of flexion. Gross image of the beta-tricalcium phosphate ( $\beta$ -TCP) being trimmed in length for proper sizing within the bony defect. (B) Right knee in 10° of flexion. Gross image of the  $\beta$ -TCP being trimmed in width for proper sizing within the bony defect.



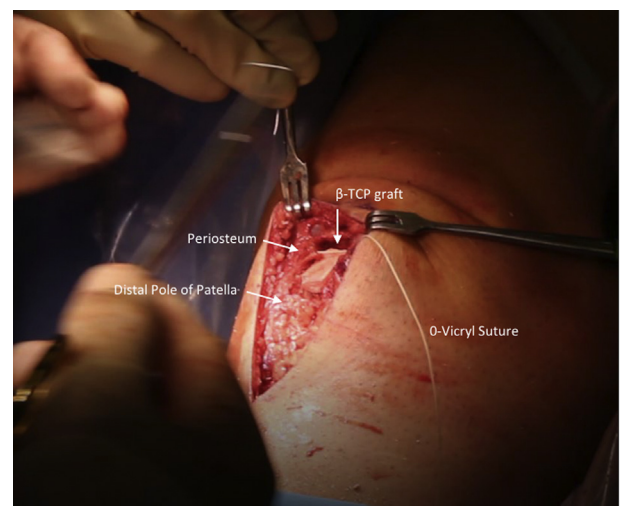
bone–patellar tendon–bone autografts are generally favorable as patients report high satisfaction, earlier return to play, and low failure rates.<sup>3,5,17</sup> Despite the satisfactory outcomes after bone–patellar tendon–bone ACL reconstruction, the most common complaint, even at long-term time points, remains postoperative anterior knee pain.<sup>3-5,18</sup> Nearly 40% of patients experience pain while walking on a hard ground and had persistent numbness overlying the knee 10 years postoperatively.<sup>19</sup>

The use of biological supplementation can potentially reduce anterior knee pain at donor sites. The use of bony autografts or protein-rich plasma to fill the defect at donor sites has demonstrated reduced anterior knee pain and improved functionality postoperatively.<sup>10,20</sup>

Although the mechanism of plasma-rich protein remains debated, autologous bone grafts offer osteoconductivity that enables bone growth at the site of deficit. However, in ACL reconstruction, the amount of cancellous bone that is obtained is generally not sufficient to fill the defect at both the tibia and patella. Synthetic grafts, such as calcium hydroxyapatite and  $\beta$ -TCP, offer osteoconductive properties similar to bony autografts. These grafts are advantageous because they reduce the morbidity associated with bony autografts and remove the variable of bone quality from determining outcomes of filling the defect. In a prospective case series using  $\beta$ -TCP grafts within the patellar and tibial donor sites in ACL reconstruction, all patients were able to kneel, walk on hard ground, and perform agility exercises without pain, whereas 1 patient noted mild discomfort with walking on hard ground.<sup>14</sup>

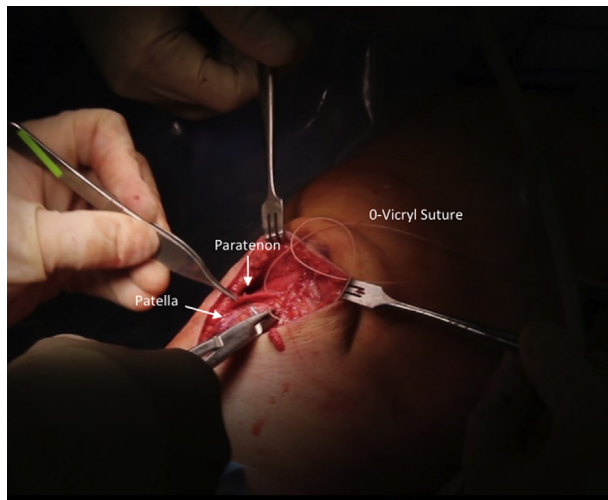


**Fig 4.** Right knee in 10° of flexion. Gross image of the proximal insertion of the patellar tendon into the distal pole of the patella. The beta-tricalcium phosphate ( $\beta$ -TCP) graft is impacted into the bony defect with a mallet and tamp to create a press fit.



**Fig 5.** Right knee in 10° of flexion. Gross image of the proximal insertion of the patellar tendon into the distal pole of the patella. A 0-Vicryl absorbable suture is used to close the periosteum over top of the graft, thus securing it in place. ( $\beta$ -TCP, beta-tricalcium phosphate.)





**Fig 6.** Right knee in 10° of flexion. Gross image of the proximal insertion of the patellar tendon into the distal pole of the patella. A 0-Vicryl absorbable suture is used to close the paratenon over top of the graft after closure of the periosteum.

Calcium hydroxyapatite and  $\beta$ -TCP have been used previously for filling the bony defect that remains in fractures or after removal of bony tumors.<sup>15</sup>  $\beta$ -TCP has shown to allow for ample bone formation and was absorbed over time, whereas calcium hydroxyapatite was not absorbed and even hindered the formation of new bone.<sup>21</sup> Nearly 2 years after placement of the  $\beta$ -TCP graft at the site of bony tumor resection, histological examination demonstrated that lamellar bone replaced the graft and there was no remaining osteoclastic or osteoblastic activity.<sup>16</sup> In a case series of 75 patients who received calcium hydroxyapatite after removal of a bony tumor, 2 patients experienced pathological fractures at the site of the graft and 2 additional patients reported persistent pain at the graft site.<sup>22</sup> Conversely, in a series of 53 patients receiving  $\beta$ -TCP grafts after the removal of a bony tumor, there were no instances of pathological fractures.<sup>23</sup> The superiority of  $\beta$ -TCP in bone regeneration is hypothesized to be due to the presence of microfibrils within the

**Table 1.** Pearls and Pitfalls of  $\beta$ -TCP Application

Pearls	Pitfalls
Use of sagittal saw allows accurate sizing and shaping of the graft	Failure to properly shape the graft may result in treatment failure
Placement of cancellous bone on the $\beta$ -TCP graft may facilitate graft incorporation	Inappropriate fixation of the graft within the donor site may lead to patient discomfort or graft failure
An absorbable suture prevents the possibility of a foreign body reaction as it may occur with a nonabsorbable suture	

$\beta$ -TCP, beta-tricalcium phosphate.

**Table 2.** Advantages and Disadvantages of  $\beta$ -TCP Application

Advantages	Disadvantages
No donor-site morbidity	Increased operative time
Greater graft availability	Added cost to patient
Ease of sizing the graft to conform to the donor site	
Improved donor site discomfort in bone–patellar tendon–bone donor sites	

$\beta$ -TCP graft that allows for early resorption by osteoclasts, neovascularization, and osteoblastic activity, which allows for replacement of the graft with de novo bone.<sup>16</sup> Histological evaluation of the implanted  $\beta$ -TCP graft demonstrates that newly formed bone is directly connected between the  $\beta$ -TCP graft and pre-existing native bone.<sup>15,16</sup>

Although the use of  $\beta$ -TCP confers clinical benefit in ACL reconstruction, the procedure of placing the graft into donor sites is not without risks. Creating a graft that is too large may result in cosmetic deformity or discomfort with kneeling or ambulation. On the other hand, shaping a graft that is too small may reduce the efficacy of the  $\beta$ -TCP graft as movement may dislodge the graft within the donor site, thus preventing replacement of the graft with de novo bony tissue. In addition, failure to adequately secure the graft into the donor site with the periosteum may lead to graft slippage or failure in the postoperative period. Advantages and disadvantages of using this technique are illustrated in Table 2.

Although there are some risks associated with the use of a  $\beta$ -TCP, it assists in bone regeneration at donor sites while improving patient outcomes and minimizing complications experienced by patients after bone–patellar tendon–bone autograft ACL reconstruction, such as quadriceps weakness, flexion contracture, and patellofemoral pain.<sup>14,24</sup> This simple technique that is performed at the end of bone–patellar tendon–bone autograft ACL reconstruction can reduce persistent anterior knee pain and improve patient satisfaction.

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