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# Medial Femoral Condyle Vascularized Bone Graft for Treatment of Midshaft Clavicle Recalcitrant Nonunion With Use of the Transverse Cervical Artery as an Anastomosis

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The study obtained exempt status by our institutional review board.

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## Abstract

Vascularized medial femoral condyle bone grafts have been reported to be a reliable treatment for recalcitrant bony nonunions of the extremities. Although clavicle fracture nonunions are rare after treatment with open reduction internal fixation, symptomatic nonunions can be a challenge. The medial femoral condyle vascularized bone graft has been described as a treatment option for clavicle nonunions with the thoracoacromial trunk as the recipient anastomosis site. This case illustrates how the transverse cervical artery and accompanying veins can be used as an anastomosis when the thoracoacromial trunk is inaccessible because of previous surgical- and infection-related scarring. At the final follow-up, the patient had returned to full duty and resumed competitive triathlons. Radiographs demonstrated complete healing of clavicle fracture.

Nonunion of the clavicle after osteosynthesis is well studied.<sup>1-4</sup> Vascularized periosteal bone grafts have proven successful compared with other techniques after chronic nonunion because the periosteal flap can be wrapped circumferentially around the defect.<sup>5-11</sup> This success transcends multiple causes for clavicular nonunion to include radiation injury and infected hardware necessitating removal.<sup>10,11</sup> The vascularized periosteal flap can be taken from multiple sources to include the fibula, radius, scapula, iliac crest, medial femoral condyle (MFC) and supracondylar regions.<sup>12,13</sup> Use of the medial femoral

condyle has been shown to be favorable, with low long-term donor site morbidity and high rates of successful grafting.<sup>14-17</sup> Packing vascularized periosteal bone grafts for clavicular nonunion with cancellous bone has been demonstrated as superior to vascular periosteal bone grafts alone or cancellous bone graft alone.<sup>18,19</sup> The thoracoacromial trunk has been consistently used for anastomosis with the vascularized periosteal bone graft for clavicular nonunion.<sup>5,10</sup> This case demonstrates the anastomosis of a vascularized medial femoral condyle bone graft with the transverse cervical artery.

Figure 1



Injury plain film radiograph demonstrating comminuted midshaft right clavicle fracture.

Figure 2



20 months after injury, plain film radiograph demonstrating persistent nonunion and hardware failure.

## Case Report

A healthy active duty 24-year-old woman who, 2 years before presentation, presented as a polytrauma at an outside hospital. She was a helmeted rider of a moped and sustained multiple injuries after she was thrown over her handlebars and landed in oncoming traffic. Her orthopaedic injuries included a right closed clavicle fracture (Figure 1) and a left knee anterior cruciate ligament tear. The left knee was treated with a delayed anterior cruciate ligament reconstruction with hamstring autograft at our institution

by one of our orthopaedic sports surgeons. Her nonorthopaedic injuries included a traumatic brain injury and a traumatic left hemopneumothorax. The patient was initially stabilized as inpatient and discharged 1 week after injury.

Two weeks after injury, the patient was indicated for open reduction and internal fixation of her left clavicle with two lag screws and a superior plate. This was indicated to improve mobility and upper extremity function. The surgical construct was then revised to an anterior plate 3 months after injury after a nonunion was diagnosed. Operative cultures from her second

surgery resulted negative for any bacterial growth. At 1 year and 6 months after injury, she was diagnosed with a symptomatic fibrous nonunion and underwent a third surgery with revision open reduction and internal fixation with iliac crest autograft. Screening operative cultures from her revision operation resulted as positive for *Cutibacterium acnes* infection. One year and 8 months after injury, the plate and unincorporated iliac crest autograft were removed. This resulted in an approximately 2.5-cm bony defect. An antibiotic spacer was placed in the clavicle bony defect (Figures 2 and 3). Two months after debridement and antibiotic spacer placement, upon the completion of an antibiotic treatment with intravenous vancomycin, a final attempt at fixation was made with the use of a vascularized medial femoral condyle bone graft. An anastomosis to the transverse cervical artery was chosen as significant postsurgical scarring was encountered in the region surrounding the clavicle and thoracoacromial trunk (Figure 4).

At follow-up at 2 years and 4 months from the initial injury (6 months after vascularized graft placement), the patient underwent a final hardware removal because of symptomatic hardware irritation. Bony union was verified radiographically on plain x-ray films. At the time of final surgery, she was found to have no residual infection and was found to have obtained complete bony union with circumferential cortical bridging of all four cortices. Final examination at 3 years demonstrated that she had full range of motion and strength about her right shoulder,

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20 months after injury, plain film radiograph showing clavicle debridement, hardware removal and antibiotic spaced placement. Intra-operative pathology assessment consistent with osteomyelitis and infected non-union.

remained pain free, and had successfully completed a triathlon race.

### Operative Technique

At the clavicle surgical site, the antibiotic spacer was identified and removed in its entirety. A curet was then used to clean out the fracture site, until the bone edges on either side were demonstrated to have adequate bleeding. Frozen sections from the nonunion site were confirmed to be negative for any evidence of persistent infection.

A head and neck microvascular surgeon then harvested the transverse cervical artery as a donor arterial supply. A subplatysmal flap was raised cephalad to the anterior border of the trapezius muscle. A level 5 neck dissection was performed, removing the lymphofatty contents to expose the transverse cervical artery and protect the remaining neurovascular structures. A small external jugular vein branch, coursing laterally across the supraclavicular fossa, was ligated cephalad and rotated down into the operative site for use as the donor vein. The transverse cervical artery was also identified coursing laterally across the supraclavicular fossa. This was identified in level 4 by finding the phrenic nerve. The transverse cervical artery was skeletonized and traced laterally until it pierced the trapezius muscle. This was ligated distally and freed up circumferentially and then it



22 months after injury, plain film radiograph demonstrating placement of MFC vascularized bone graft and anterior plating.

was rotated back toward level 4. The inferior thyroid artery take off branch was clipped and ligated to facilitate a greater arc of rotation of the blood vessel.

The technique of harvesting the free vascularized ipsilateral medial femoral condyle was done using the described technique by Masquelet and popularized by Doi et al.<sup>14-17</sup> The vascular pedicle was isolated to a given length of 8 cm in the supracondylar periosteum, a 3 × 3 cm cortical cancellous block was elevated from the medial femoral condyle based on the descending geniculate artery.

The medial femoral condyle was then brought to the clavicle recipient site. It was shaped to fit the clavicle defect. The pedicle and the periosteum were placed anterior so as to facilitate the orientation cephalad to reach the anastomosis site. Once the medial femoral condyle graft was inserted into the clavicle defect an anterior bridge plate was placed to fix the distal and proximal clavicle bone pieces. Compression was obtained through the plate because no screws were placed on the medial femoral condyle. At this time, the microvascular anastomosis was performed. The recipient and donor vessels were anastomosed end to end with interrupted 9-0 nylon using standard microvascular techniques.

To protect the anastomosis postoperatively, an arm immobilizer was used for 6 weeks with occupation therapy-guided limited range of motion. After 6 weeks, both unrestricted active and passive range of motion were then initiated. Full weight-bearing of the upper extremity was allowed at 8 weeks once the union was confirmed on plain radiograph films. Immediate full weight-bearing was allowed to the ipsilateral donor leg.

### Discussion

Clavicle fractures are a common injury, although many can be treated successfully without operation; in the setting of polytrauma, operative intervention is often preferred. The nonunion rates for nonoperative management are reported to be from 1% to 15%.<sup>1,2</sup> Nonunion after operative treatment is a much rarer occurrence ranging from 1.4% to 4.6%.<sup>4</sup> The risks factors for nonunion after operative treatment include predisposing factors (ie, smoking and diabetes), nature of injury (ie, open fractures), or infection.<sup>4</sup> The correlation with infection and nonunion has been reported to be as high as 83% in one case study by Gausden et al,<sup>4</sup> with *P acnes* identified as the causative organism 78% of the time. When nonunion does occur, open reduction and plate fixation with nonvascularized bone graft often suffices.

However, the problem of nonunion after multiple surgical efforts becomes more challenging.

For clavicle nonunion treatment, options include compression plating with autologous graft or demineralized bone matrix or the use of a vascularized bone graft. The literature reports successful results with use of vascularized rib transfer and even fibular strut grafts; however, the use of the medial femoral condyle vascularized graft has become the most widely used graft of choice.<sup>9</sup> Vascularized fibular strut grafts have been shown to have a high failure rate when used at the clavicular site.<sup>10</sup> Vascularized MFC grafts have been shown to have superior union rates compared with the iliac crest autograft.<sup>9-11</sup> One study by Hamada et al<sup>9</sup> demonstrated a 100% union rate with the use of vascularized medial femoral condyle graft with an average healing time of 2 months.

Both a vascularized medial femoral condyle periosteal sleeve or a corticoperiosteal bone graft have been described for the treatment of recalcitrant clavicle nonunions. The ipsilateral leg is often used for the ease of access in surgery. The most common site of anastomosis has been the thoracoacromial trunk, which arises from the subclavical vessels.<sup>5,10</sup> Although not well described in the orthopaedic literature, in the plastic surgery and otorhinolaryngology literature, they frequently cite the use of transverse cervical vessels as recipient vessels for surgical reconstructions of head and neck cancer patients.<sup>2</sup> Anatomical studies have shown that the transverse cervical vessels are reliable recipients as 82% of specimens have artery di-

ameters measuring 2 to 3mm and only 6% of veins had a diameter less than 2 mm.<sup>19</sup>

Although the use of a vascularized medial femoral condyle graft has been well described in the orthopaedic surgery literature for the treatment of recalcitrant clavicle nonunions, in the case of severe scarring either due to multiple surgeries or infection, the use of the transverse cervical vessels as an anastomosis site is a surgical treatment option.

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