CHAPTER **30**

A Viable Osteochondral Allograft for Articular Cartilage Replacement of the First Metatarsal Head: A Case Series

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INTRODUCTION

Cryopreserved, viable osteochondral allograft (CVOCA) has been shown to retain viable chondrocytes, chondrogenic growth factors, and extracellular matrix proteins within a natural laminar architecture of cartilage (1). It has shown to be an effective treatment option for articular cartilage repair of lesions involving lateral and medial femoral condyles, patellas, trochleas, tibial plateaus, and talar domes (2-5). However, to date, there have been no publications presenting the clinical outcomes following the use of CVOCA on the first metatarsophalangeal joint.

Currently, there are a variety of widely-used joint-preserving and joint-destructive procedures to address articular cartilage damage in the first metatarsophalangeal joint, although there is no consensus among experts on which method is superior or even which outcome scoring system best evaluates patient progress. In the literature, several of these procedures have been shown to be effective, although each one has well-known limitations and potential complications (6,7) leaving the door open for exploration of other surgical options. The ideal treatment for end-stage first metatarsophalangeal joint cartilage damage would eliminate pain, achieve good alignment and cosmesis, maintain the medial column and toe length, and allow the patient to regain full range of movement as well as normal foot function and gait pattern (8).

Nonoperative therapies such as topical analgesic medications, physical therapy, and footwear modifications are typical first-line treatment options for early stage hallux limitus and hallux rigidus caused by degenerative joint disease; however, there is little evidence in the literature to support these therapies (9). In some cases, motion exercises in physical therapy may actually worsen symptoms if normal range of motion restoration is forced (10).

Cheilectomy and decompressional metatarsal osteotomy are common joint-preserving procedures for intermediate stage hallux limitus. Despite the prevalence of these treatments, there is some debate regarding the surgical technique and approximate amount of bone that should be resected during these procedures. Microfracture, abrasion arthroplasty, and osteochondral grafting are additional joint-preserving treatment options, but they do not involve bone resection by definition. Instead, the damaged articular joint cartilage is either debrided, stimulated, or replaced with a cartilage graft. In some cases, these procedures can be coupled with a bone resection procedure. In a literature review of joint-preserving and joint-destructive procedures in 2014, Polzer et al found that the clinical heterogeneity between the well-known procedures as well as the modified procedures, coupled with the low number of relevant published prospective trials makes it difficult to draw any solid conclusions comparing clinical outcomes of both joint-preserving and joint-destructive treatments (11). Even without the ability to effectively compare outcomes of these procedures, in general, joint-preserving surgeries are still quite a desirable option for physicians because in the cases where the surgery is not successful (for example, when the patient's pain is persistent), the joint is still intact enough for a subsequent, more "destructive" secondary treatment option.

The 2 most common joint-destructive procedures for the treatment of hallux rigidus are joint arthroplasty with replacement (either total or hemi) and arthrodesis, which is the surgical fusion of the first metatarsal and the proximal phalanx bones. Arthrodesis, first documented as early as 1852, has been shown to be effective from a pain management perspective and superior to total joint arthroplasty in clinical outcomes, although the obvious limitation of this procedure is irreversible joint immobility (8,12,13). Clinical outcomes for joint arthroplasty vary due to the variety of techniques and materials used for this procedure, but patient satisfaction has been reported to be lower than arthrodesis (83.2% compared to 96.3%), with no significant difference between total and hemi arthroplasty, and no significant difference between silicone and metal joint material (12,14). The ultimate goal for joint arthroplasty, as the technology progresses, is to match the success rates of arthrodesis, while preserving the mobility of the joint (8). In this article, we present the surgical technique and results of a case series using CVOCA in a novel joint-preserving procedure for the treatment of end-stage first metatarsophalangeal joint cartilage damage.

PATIENTS AND METHODS

From October 2015 to October 2016, at one surgical center, the senior author (PW) performed surgery for end-stage arthritic cartilage damage of the first metatarsal head secondary to significant hallux limitus, utilizing implantation of CVOCA in all 4 cases. Two men and two women, with an average age of 50.25 years (range 35 to 56 years), were treated. There were no notable comorbidities or significant medical histories except for 1 patient with a history of gout who was asymptomatic at the time of surgery (Table 1).

All 4 patients presented with very similar symptoms and clinical pictures, which included significant, progressing pain, and limited range of motion of the first metatarsophalangeal joint. Preoperative radiographs were obtained for each patient, which revealed non-uniform joint space narrowing, subchondral sclerosis, osteophytosis, and severe flattening of the first metatarsal head. Patients were staged using the Hattrup and Johnson staging system (Table 1).Three of the patients were Stage 3 and 1 patient was Stage 4 (Table 2). All 4 patients were classified as having severe hallux limitus/cartilage damage according to the definitions Coughlin and Shurnas (Table 3). Radiograph and clinical follow-up was obtained for every patient at a minimum of 10 months postoperation to evaluate progress. According to the regulations of the Department of Health and Human Services, a retrospective case report does not require Institutional Review Board approval, and all HIPAA identifiers were removed from the data.

SURGICAL TECHNIQUE

The cartilage was completely denuded off the first metatarsal head (Figure 2), and a thawed and prepared 20 mm CVOCA disc was placed directly on the bone. The graft was secured using crossing fiberwire sutures passed from plantar-lateral to dorsal-medial and plantar-medial to dorsal-lateral through crossing drill holes in the neck of the first metatarsal. The sutures passed through 4 spots on the graft equi-distant from each other circumferentially. Two additional sutures from dorsal-medial to plantar-lateral and dorsal-lateral to plantar-medial were passed through the same drill holes (Figure 2). The sutures were tightened and secured with 2 3.2 biotenodesis screws through the dorsal holes to prevent suture pull out (Figure 2). In 3 of the patients, a mini-monorail external fixator was applied for 1 month, which provided traction across the first metatarsophalangeal joint while the graft was allowed to incorporate. All patients were full weightbearing immediately after surgery and returned to normal shoe wear approximately 1 month after surgery, immediately following external fixation removal (when applicable).

Table 1. Patient Demographics

	Sex	Age	Co-Morbidities	Coughlin & Shurnas Stage	Hattrup & Johnson Stage
Case 1	F	55	None	3	3
Case 2	M	55	None	3	3
Case 3	M	35	History of gout	3	3
Case 4	F	56	None	3	4

Table 2. Coughlin & Shurnas Classification of Hallux Limitus

Grade 1	Mild changes with a maintained joint space and minimal spurring.
Grade 2	Moderate changes, joint space narrowing, bony proliferation of the MT head, and phalanx, and subchondral sclerosis.
Grade 3	Severe changes with moderate to severe join space narrowing, extensive bony proliferation, and loose bodies or a dorsal ossicle.

Table 3. Hattrup & Johnson Classification of hallux limitus

Grade 0	DF of 40-60 degrees (20% loss of normal motion), normal radiographic results, no pain.
Grade 1	DF of 30-60 degrees, dorsal osteophytes, and minimal to no other joint changes.
Grade 2	DF of 10-30 degrees, mild flattening of the MTP joint, mild to moderate joint space narrowing or sclerosis, and osteophytes.
Grade 3	DF less than 10 degrees, often less than 10 degrees PF, severe radiographic changes with hypertrophied cysts or erosions or with irregular sesamoids, constant moderate to severe pain, and pain at the extremes ROM.
Grade 4	Stiff joint, radiographs showing loose bodies or osteochondral defects, and pain throughout entire ROM.

RESULTS

Excellent clinical results were demonstrated by a significant reduction in visual analog scale (VAS) score outcomes, where pain intensity is measured on a scale of 0 to 10 where 0 = no pain and 10 = worst imaginable pain. The average preoperative VAS score for the 4 patients was 8.0, the average 1-month postoperative VAS score was 2.5, and the average 8-month postoperative VAS score was 0 (Table 4). Additionally, dorsiflexion range of motion at the first metatarsophalangeal joint increased from an average of 4.25 degrees preoperatively to 58.25 degrees postoperatively (Table 5).

Radiographic results showed an average increased first metatarsal joint space from 1.1 mm, 1.5 mm, and 2.2 mm from medial to lateral on the dorsoplantar (DP) view preoperatively, to 3.1 m, 2.8 mm, and 3.1 mm, respectively, 8 months postoperatively (Table 6 and Figure 1).

Continued excellent patient satisfaction was observed for all patients, ranging from 10 to 22 months follow-up postoperatively. At the final follow-up time point, each patient had returned to full activity with minimal pain, no recurrence of joint space narrowing, and 100% reported patient satisfaction with the procedure outcome.

Table 4. Visual analog scale pain score outcomes

	Preoperative	8 Month Postoperative
Case 1	8	0
Case 2	9	0
Case 3	7	0
Case 4	8	0
Average	8.0	0.0

Table 5. Hallux dorsiflexion outcomes

	Preoperative	8 Month Postoperative
Case 1	5°	55°
Case 2	7°	58°
Case 3	5°	60°
Case 4	0°	60°
Average	4.3°	58.3°

Table 6. Dorsoplantar radiograph outcomes: joint space

	Preoperative (mm) Medial, Central, Lateral	Immediate Postoperative (mm) Medial, Central, Lateral	8 Month Postoperative (mm) Medial, Central, Lateral
Case 1	1.0, 1.9, 2.0	3.5, 2.8, 3.3	3.4, 2.8, 3.1
Case 2	1.3, 1.4, 2.1	3.3, 2.9, 3.3	3.1, 2.7, 3.1
Case 3	1.2, 1.5, 2.6	3.2, 3.2, 3.4	2.9, 3.0, 3.1
Case 4	0.9, 1.3, 1.9	3.3, 3.0, 3.4	3.0, 2.8, 3.0
Average	1.1, 1.5, 2.2	3.3, 3.0, 3.4	3.1, 2.8, 3.1

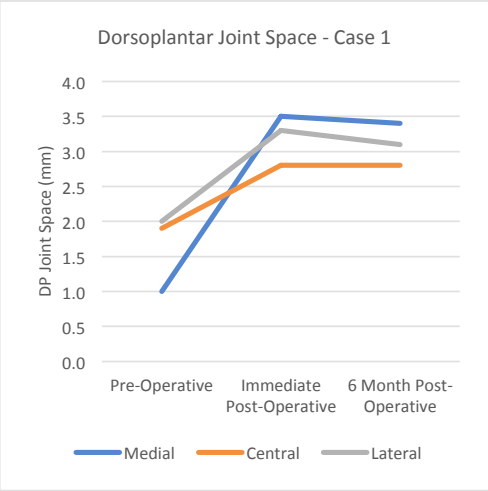

Figure 1A. Dorsoplantar radiograph outcomes for joint space: Case 1.

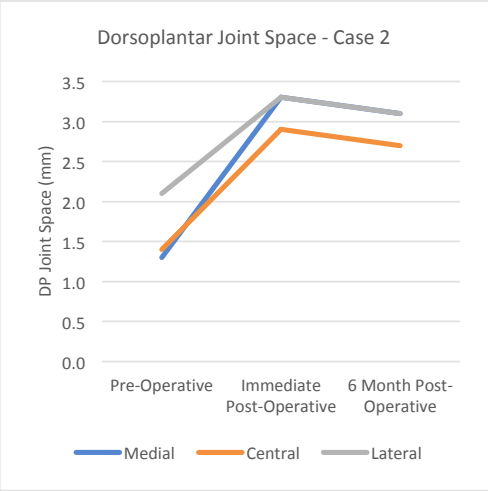

Figure 1B. Dorseplantar joint space outcomes: Case 2.

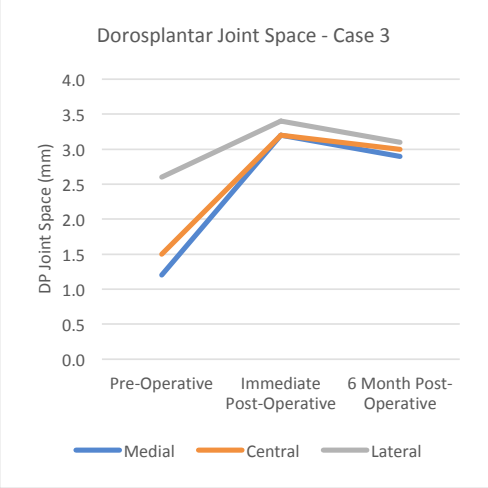

Figure 1C. Forsoplantor radiograph outcomes: Case 3.

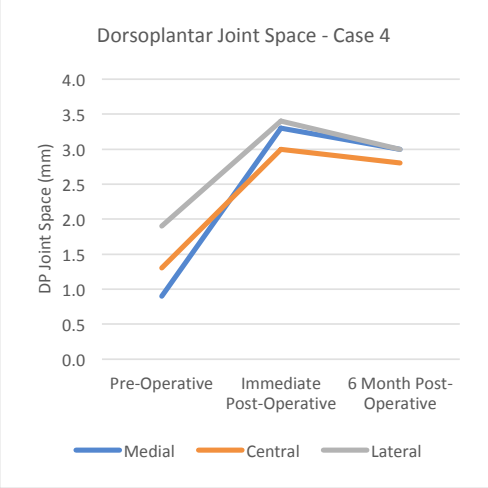

Figure 1D. Dorsoplantar joint space: Case 4.

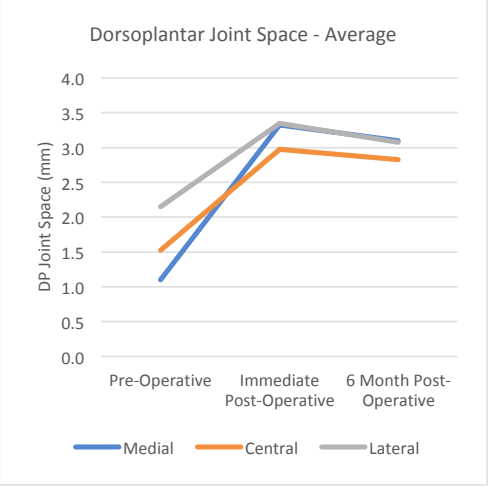

Figure 1E. Dorsoplantor radiograph outcomes: Average.

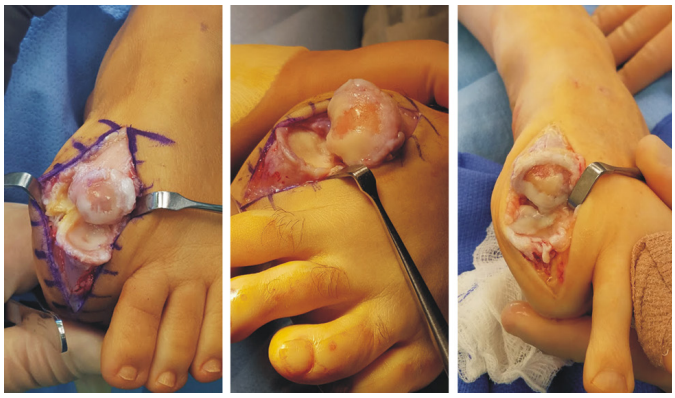

Figure 2. Cryopreserved, viable osteochondral allograft (CVOCA) implantation. A-C, Preimplantation of CVOCA.

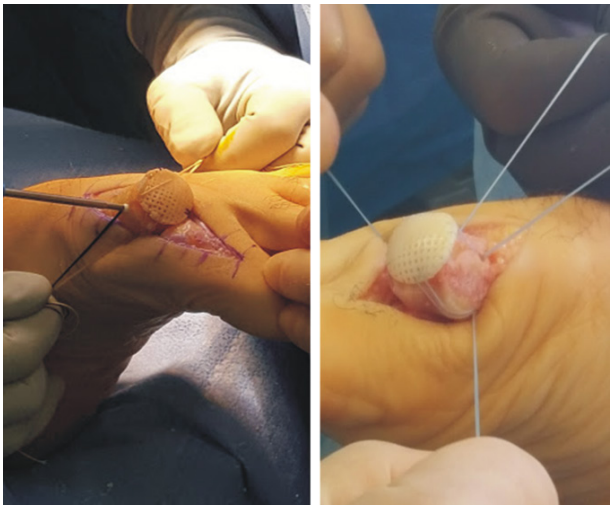

Figure 2D-E. Suturing and securing the CVOCA to the first metatarsal head.

Figure 2 F-G. Completion of CVOCA implantation to the first metatarsal head.

DISCUSSION

Despite the prevalence of end-stage degenerative joint disease of the first metatarsophalangeal joint, there is debate among foot and ankle surgeons as to the most effective and durable treatment option. A patient's age, daily activity level, and expectations of surgery further complicate a surgeon's decision of which procedure is best for each specific patient. Currently, the most common procedures to treat end-stage degenerative joint disease of the first metatarsophalangeal joint include first-line nonoperative therapies, joint-preserving procedures, and joint-destructive procedures.

In 2017, Kon Kam King et al published a comprehensive review of nonoperative management of hallux rigidus, a form of degenerative arthritis, reporting that there is poor evidence in support of manipulation and physical therapy as well as modifications in footwear, insoles and orthotics for the treatment of hallux rigidus. Additionally, the evidence-based review demonstrated that there is poor evidence for the use of intra-articular injections for short-term pain relief, and only fair evidence for the use of injections for long-term efficacy. More importantly, out of all of the nonoperative interventions included in the analysis, none could be supported with "good evidence" (9). Despite the lack of published evidence to support the use of nonoperative management of degenerative joint disease of the first metatarsophalangeal joint, these therapies are often offered to patients as a first-line treatment in an attempt to avoid invasive procedures.

In cases where nonoperative treatment does not succeed, surgeons will often perform a joint-preserving procedure such as a cheilectomy or a decompressional metatarsal osteotomy. Good clinical outcomes and high patient satisfaction, including a 97% patient satisfaction rating for the Youngswick procedure, have been reported in the literature for both of these procedures; however, in cases of patients with end-stage disease and extensive cartilage damage of the first metatarsal head, a joint-preserving procedure may only offer very short-term pain relief. In end-stage degenerative joint disease, the root cause of the pain and immobility of the joint is extensive cartilage damage on the surface of the first metatarsal head. A joint-preserving procedure would not address this, and may only temporarily relieve pain by slightly increasing the joint space between the first metatarsal bone and the proximal phalanx (15).

A surgeon may resort to a joint-destructive procedure in the event that a joint-preserving procedure fails, or if a patient initially presents with end-stage degenerative joint disease. First described by Broca in 1852, arthrodesis of the first joint is considered the gold standard joint-destructive procedure by many experts; however, because of the resulting immobility of the joint, it may only be suitable for a select few patients (16). In a randomized, controlled trial comparing arthrodesis and total joint arthroplasty for the treatment of hallux rigidus, Stone et al demonstrated that arthrodesis outperformed arthroplasty in all validated outcome measures up to 15 years post-surgery (12). Despite the strong evidence of clinical efficacy and durability, arthrodesis is not an option for many patients, specifically younger patients or those who cannot maintain their preferred daily levels of activity without the mobility of their first metatarsal joint. In these cases, a total joint arthroplasty may be necessary.

Although there is an abundance of published data presenting total joint arthroplasty clinical outcomes, in the past it has been difficult to effectively compare these clinical outcomes due to the varying surgical techniques, the wide variety of joint materials used, and recent surgical advances. However, in 2009 Cook et al performed a historic analysis

of over 3,000 total joint arthroplasty cases and found that there was no significant difference in clinical outcomes between silicone, metal, and ceramic joint material, nor was there a significant difference in outcomes between a total joint arthroplasty and a partial joint arthroplasty. In either case, Cook et al found overall patient satisfaction for the joint arthroplasty procedure to be 85.7%, with Stone et al finding overall patient satisfaction for the joint arthroplasty procedure to be 83.2%, lower than their reported 96.3% for patient satisfaction following arthrodesis surgery (12,14).

Durability outcomes of total joint arthroplasty have been reported as high as 86% for overall survivorship of implants in 10 years and 82% in 15 years, though it has also been demonstrated that more than 1 in 8 patients who have had a joint arthroplasty end up requiring a subsequent arthrodesis surgery due to persistent symptoms or malalignment (17,18). A secondary procedure may also be necessary if the arthroplasty surgery did not effectively neutralize the underlying deforming forces that caused the articular damage in the first place. This is a high risk for total joint arthroplasty patients who wish to preserve mobility at the first metatarsophalangeal joint, because a failed total joint arthroplasty leaves them with limited choices. In an evidence-based review of published studies, McNeil et al found that there is "poor evidence" in support of total joint arthroplasty for the treatment of hallux rigidus, and only "fair evidence" in support of arthrodesis, leaving only substandard treatment options for patients who have had an unsuccessful joint-preserving surgery and patients with end-stage degenerative articular cartilage disease (13).

Both the published literature and clinical experience have demonstrated that there is no universal joint preserving or joint destructive procedure to effectively address the common yet complex problem of degenerative joint disease of the first metatarsophalangeal joint. The success of any given procedure seems to vary depending on which literature review, physician or patient you consult. The single aspect of each treatment approach that is consistent, however, is the end goal. In light of our body's inability to regenerate articular cartilage, researchers and physicians strive to find a durable joint substitute that can stand the test of time and stress, while eliminating pain, and restoring function. Positive clinical outcomes of CVOCA for the treatment of degenerative joint disease of the first metatarsophalangeal joint indicate that we are one step further to achieving that goal.

CVOCA is harvested from donated human cadaveric tissue, and advances in cryopreservation techniques have allowed the graft to maintain the intact native cartilage structure with maximum cell viability of chondrocytes, growth factors, and extracellular matrix proteins (1). The porated design of CVOCA allows for maximum cryoprotectant penetration during the cryopreservation process, as well as increases the physical flexibility of the graft, allowing for ease of implantation and the ability to match the contour of many joint surfaces (1).

CVOCA has been shown to be effective in cartilage repair in several different joint surfaces of the body. Hoffman et al (5) and Vangsness et al (2) have demonstrated good results with CVOCA used for articular cartilage repair in the knee. In a systematic review of 5 studies on osteochondral allograft for treatment of osteochondral lesions of the talus, VanTienderen presented improvement of AOFAS scores and VAS scores over long term follow-up for CVOCA implantation, and concluded that the CVOCA can substantially improve functional status (5). To date, however, there are no clinical studies showing the validity of the CVOCA to address articular cartilage damage of the first metatarsophalangeal joint.

In this case series, we report 100% satisfaction following a complete cartilage replacement with a CVOCA graft. Limitations of the report include a small sample size and a relatively short follow-up period of 1 year. A variety of surgical methods were described for the 4 cases, however, that can be viewed not as a limitation of the study, but as a demonstration of the CVOCA's diversity. Varying methods of fixation, depending on surgeon preference and personal experience, do not appear to affect the positive clinical outcome of any case. Our goal in presenting this research was to demonstrate the viability of this cryopreserved, osteochondral allograft as a viable treatment option for degenerative articular cartilage disease of the first metatarsal joint, which preserves joint function, eliminates pain, and allows for a quick and full recovery.

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