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

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## ABSTRACT

Few reports in the literature have described the use of an osteochondral allograft for the treatment of articular cartilage damage of the 1st metatarsal phalangeal joint. We present here the clinical outcomes and detailed surgical technique of four cases in which we used a cryopreserved, viable, osteochondral allograft (CVOCA) for full cartilage replacement of the first metatarsal head to address degenerative articular cartilage damage. At 10-22 months of follow-up, patients reported clinical improvement, with VAS pain-scale scores decreasing from an average of 8.0 to 0 post-operatively, and range-of-motion improvement from an average of 4.3 degrees to 58.3 degrees dorsiflexion. Radiographic improvement was also seen, with an increase in average joint space from 1.1mm, 1.5mm, and 2.2mm from medial to lateral on dorsoplantar views pre-operatively, to 3.1mm, 2.8mm, and 3.1mm 15 months post-operatively, respectively. These results suggest that CVOCA is a desirable treatment option for end-stage degenerative joint disease of the first metatarsal phalangeal joint.

## 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] and 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, there have been no previous reports on the clinical outcomes following the use of CVOCA on the 1st metatarsal phalangeal joint.

Currently, there are a variety of widely-used joint-preserving and joint-destructive procedures to address articular cartilage damage in the 1st metatarsal phalangeal joint, though there is no consensus among experts on which method is superior or even which outcome scoring system best evaluates patient progress. While several of these procedures have been shown to be effective, each has well-known limitations and potential complications,[6,7] which prompts efforts to identify other surgical options. The ideal treatment for end-stage 1st metatarsal phalangeal 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 motion as well as normal foot function and gait pattern.[8]

Non-operative therapies such as topical analgesic medications, physical therapy, and modification in footwear are typical first-line treatment options for early-stage hallux limitus and hallux rigidus caused by degenerative joint disease, however, there is poor evidence in the literature to support these therapies.[9] In some cases, motion exercises in physical therapy may actually worsen symptoms if the return to a normal range of motion is forced.[10]

Cheilectomy and de-compressional 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, which, by definition, do not involve bone resection. 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 2014 literature review of joint-preserving and joint-destructive procedures, Polzer et al. found that the clinical heterogeneity between well-known procedures as well as 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 the outcomes of these procedures, in general, joint-preserving surgeries are still a desirable option for physicians because, in cases where the operation 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 two most common joint-destructive procedures for the treatment of hallux rigidus are joint arthroplasty with replacement (either

**Table I**
**Patient Demographics**

| | Sex | Age (y) | 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 II**
**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 joint-space narrowing, extensive bony proliferation, and loose bodies or a dorsal ossicle. |

**Table III**
**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. |

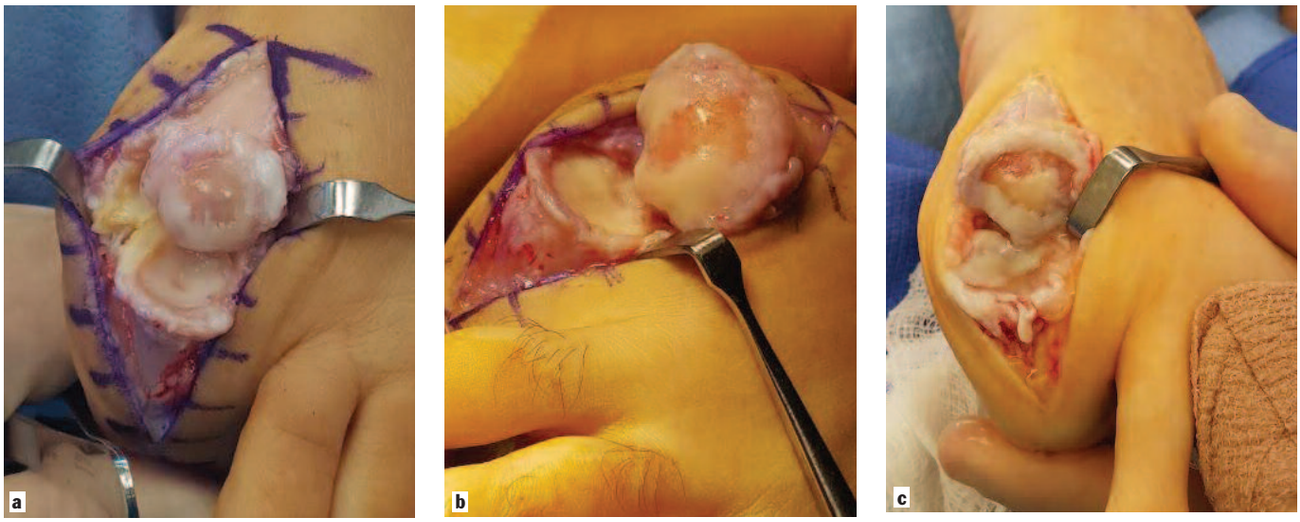


**Figure 1. Photos of CVOCA Implantation Surgery. 1a-1c: Pre-implantation of CVOCA.**

total or hemi) and arthrodesis, which is surgical fusion of the first metatarsal and the proximal phalanx bones. Arthrodesis, first documented as early as 1852, has been demonstrated to be effective from a pain-management perspective and to give superior clinical outcomes compared to total joint arthroplasty, though 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 that with arthrodesis (83.2% vs. 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 paper, 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 1st metatarsal phalangeal joint cartilage damage.

## PATIENTS AND METHODS

From October 2015 to October 2016, at a single surgical center, the senior author (PW) performed four surgeries for end-stage arthritic cartilage damage of the first metatarsal head

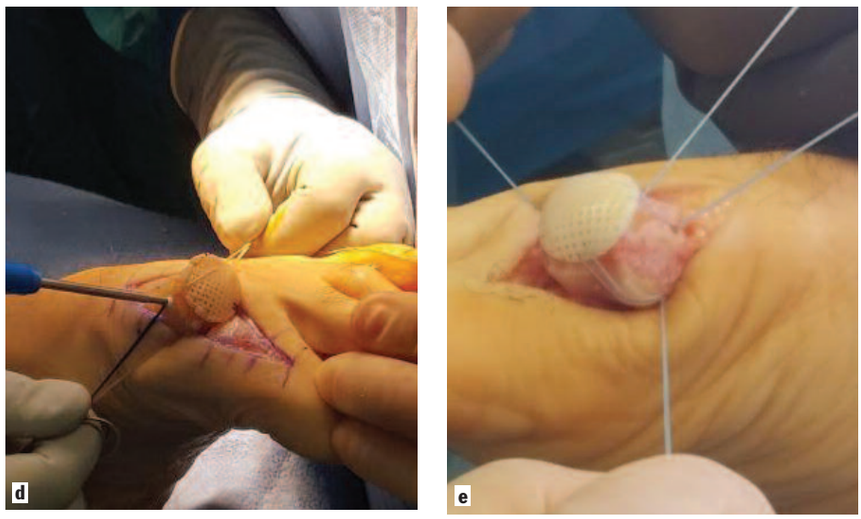


**Figure 1d,1e: Suturing and securing the CVOCA to the 1st metatarsal head.**

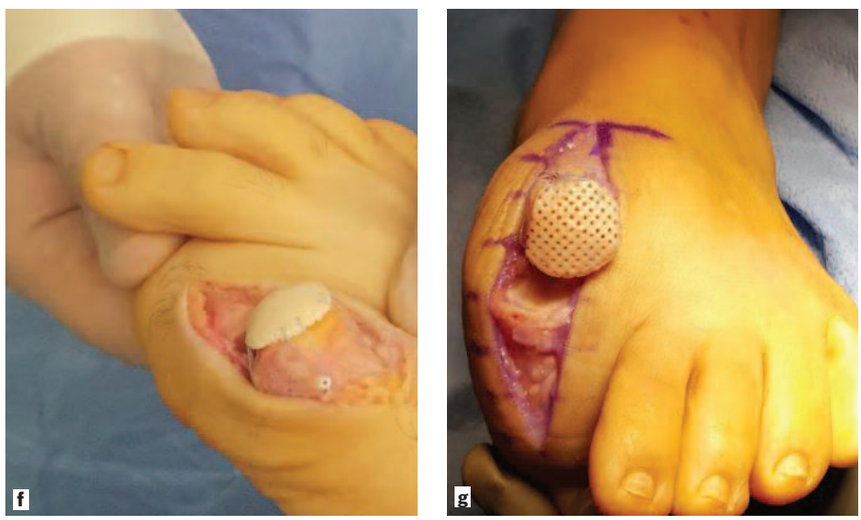


**Figure 1f,1g: Completion of CVOCA implantation to the 1st metatarsal head.**

**Table IV**
**VAS Pain Score Outcomes**

| | Pre-Operative | 15-Month Post-Operative |
|---|---|---|
| **Case 1** | 8 | 0 |
| **Case 2** | 9 | 0 |
| **Case 3** | 7 | 0 |
| **Case 4** | 8 | 0 |
| **Average** | 8.0 | 0.0 |

*VAS = visual analogue scale (1-10)*

**Table V**
**Hallux Dorsiflexion Outcomes**

| | Pre-Operative | 15-Month Post-Operative |
|---|---|---|
| **Case 1** | 5° | 55° |
| **Case 2** | 7° | 58° |
| **Case 3** | 5° | 60° |
| **Case 4** | 0° | 60° |
| **Average** | 4.3° | 58.3° |

secondary to significant hallux limitus, using implantation of CVOCA in all four cases.

Two men and two women, with an average age of 50.25 years (ranging from 35 to 56 years), were treated. There were no notable comorbidities or significant past medical histories except for one patient with a history of gout who was asymptomatic at the time of surgery (Table 1).

All four patients presented with very similar complaints and clinical pictures, including significant, progressive pain and limited range-of-motion of the 1st metatarsal phalangeal joint. Pre-operative radiographs were obtained for each patient, and revealed non-uniform joint-space narrowing, subchondral sclerosis, osteophytosis and severe flattening of the 1st metatarsal head. Using the Hattrup and Johnson staging system, three of the patients were Stage 3 and one patient was Stage 4 (Tables 1 and 2). All four cases were classified as severe hallux limitus/cartilage damage according to the classification of Coughlin and Shurnas (Tables 1 and 3).

Radiograph and clinical follow-up was obtained for every patient at a minimum of 10 months post-operation to evaluate progress.

According to the regulations of the US Department of Health and Human Services, a retrospective case report does not require Institutional Review Board approval. All HIPAA identifiers were removed from the data.

### Surgical Technique

Cartilage was completely denuded off the 1st metatarsal head (Figure 1), and a thawed and prepared 20mm 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 four spots on the graft equidistant 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 1). The sutures were tightened and secured with two 3.2 Bio-Tenodesis™ screws (Arthrex, Inc., Naples, FL) through dorsal holes to prevent suture pull-out (Figure 1). In three of the patients, a mini-monorail external fixator was applied for one month, which provided traction across the 1st metatarsal phalangeal joint while the graft was allowed to incorporate. All patients were full weight-bearing immediately and returned to normal shoe wear approximately 1 month after surgery, immediately following ex-fix removal (when applicable).

## RESULTS

Excellent clinical results were demonstrated by a significant reduction in visual analogue scale (VAS) out-

**Table VI**
**Dorsoplantar Radiograph Outcomes – Joint Space**

| | Pre-Operative (mm)<br>*Medial, Central, Lateral* | Immediate Post-Operative (mm)<br>*Medial, Central, Lateral* | 15 Month Post-Operative (mm)<br>*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 |

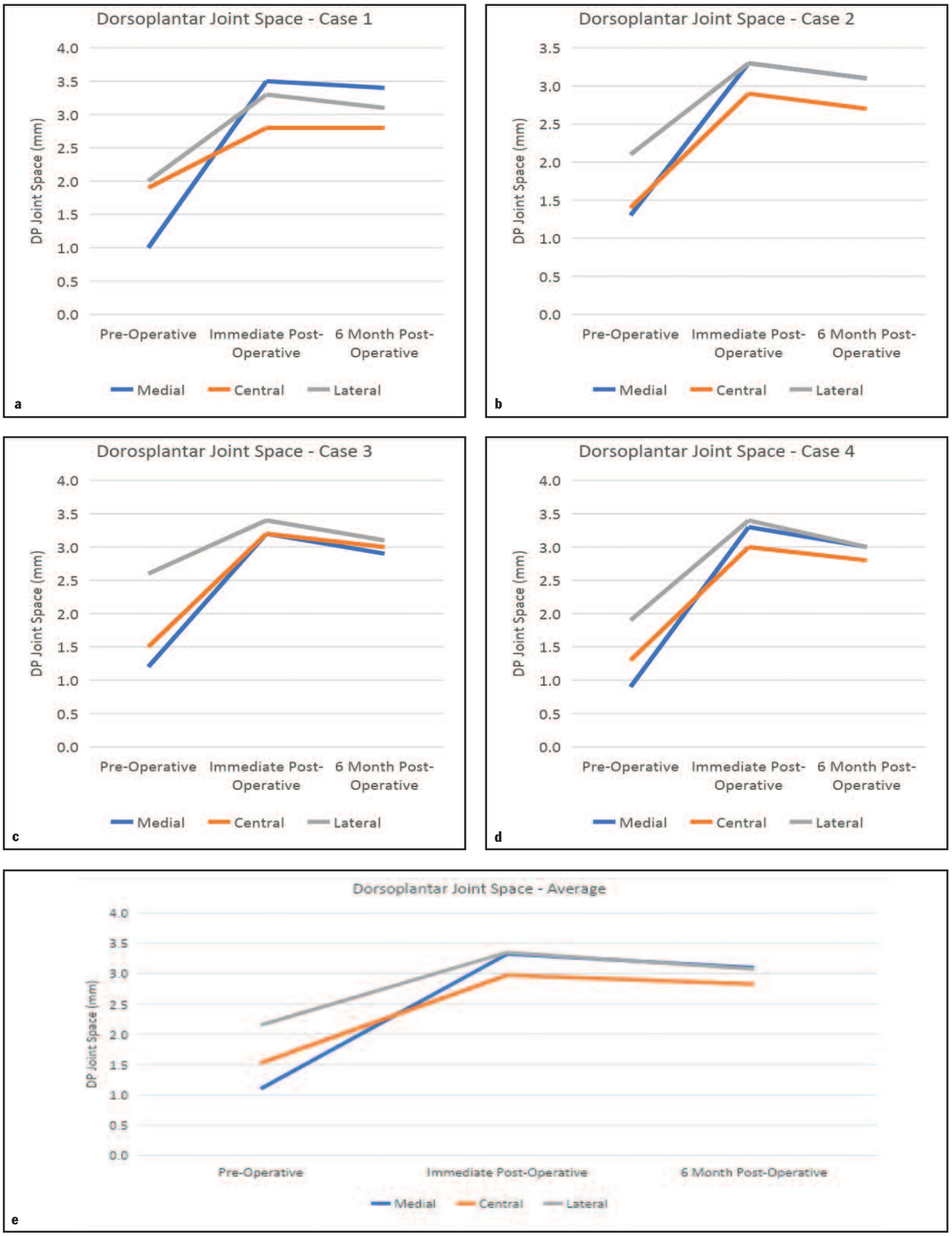


**Figure 2 a, b, c, d, e. Dorsoplantar (DP) Radiograph Outcomes – Joint Space**

comes, where pain intensity was measured on a scale of 0 ("no pain") to 10 ("pain as bad as it could be" or "worst imaginable pain"). The average pre-operative VAS score for the four patients was 8.0, the average 1-month post-operative VAS score was 2.5, and the average 15-month post-operative VAS score was 0 (Table 4). Additionally, dorsiflexion range-of-motion at the first metatarsal phalangeal joint increased from an average of 4.25 degrees pre-operatively to 58.25 degrees post-operatively (Table 5).

Radiographic results showed an average increase in the 1st metatarsal joint space from 1.1mm, 1.5mm, and 2.2mm from medial to lateral on a dorsoplantar (DP) view pre-operatively, to 3.1mm, 2.8mm, and 3.1mm, respectively, 15 months post-operatively (Table 6, Figure 2 (shows data to 6 months)).

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

## DISCUSSION

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

In 2017, Kon Kam King et al. published a comprehensive review of non-operative management of hallux rigidus, a form of degenerative arthritis, and reported that there is poor evidence to support manipulation and physical therapy as well as modifications in footwear, insoles and orthotics for the treatment of hallux rigidus. Additionally, this 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. Most importantly, among all of the non-operative interventions included in the analysis, none could be supported with "good" evidence.[9] Despite the lack of published evidence to support the non-operative management of degenerative joint disease of the 1st metatarsal phalangeal joint, these therapies are often offered to patients as a first-line treatment in an attempt to avoid invasive procedures.

In cases where non-operative treatment does not succeed, surgeons will often perform a joint-preserving procedure such as cheilectomy or de-compressional metatarsal osteotomy. Good clinical outcomes and high patient satisfaction, including a 97% patient satisfaction reported for the Youngswick procedure, have been reported for both of these procedures. However, in patients suffering from end-stage disease with 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 1st metatarsal head. A joint-preserving procedure would not address this, and may only temporarily relieve pain by slightly increasing joint space between the 1st metatarsal bone and the proximal phalanx.[15]

A surgeon may resort to a joint-destructive procedure if 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 selected 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 for 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 young 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.

While there is an abundance of published data regarding the clinical outcome of total joint arthroplasty, 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, and recent surgical advances. However, in 2009, Cook et al. performed a historical 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 total joint arthroplasty and partial joint arthroplasty. In either case, Cook et al. found that overall patient satisfaction for the joint arthroplasty procedure was 85.7%, and Stone et al. found that overall patient satisfaction for the joint arthroplasty procedure was 83.2%, which was lower than the value of 96.3% for patient satisfaction following arthrodesis surgery.[12,14] The overall survivorship of implants following total joint arthroplasty has been reported to be as high as 86% at 10 years and 82% at 15 years, though it has also been demonstrated that greater than one in eight patients who have had a joint arthroplasty end up requiring a subsequent surgery of arthrodesis 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 initially caused the articular damage. This is a high risk for total joint arthroplasty patients who wish to preserve mobility at the first metatarsal phalangeal joint, since 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 literature and our own clin-

ical experience have shown 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 metatarsal phalangeal joint. The success of any given procedure seems to vary depending on which literature review, physician or patient you consult. However, each treatment approach shares the same 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 withstand the test of time and stress, while eliminating pain and restoring function. Positive clinical outcomes with the use of CVOCA for the treatment of degenerative joint disease of the first metatarsal phalangeal joint indicate that we are one step further to achieving this 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, and 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. and Vangsness et al. demonstrated good results with CVOCA used for articular cartilage repair in the knee and, in a systematic review of five studies on osteochondral allograft for the treatment of osteochondral lesions of the talus, VanTienderen et al. presented improved AOFAS scores and VAS scores over a long-term follow-up for CVOCA implantation, and concluded that CVOCA can substantially improve functional status.[2,3,5] To date, however, there are no clinical studies showing the validity of CVOCA for addressing articular cartilage damage of the 1st metatarsal phalangeal joint.

In this case series, we report 100% patient satisfaction following a complete cartilage replacement with a CVOCA graft. Limitations of this report include a small sample size and a relatively short follow-up period of about 1 year. While a variety of surgical methods were described for the four cases, this can be viewed, not as a limitation of the study, but rather as a demonstration of the flexibility of CVOCA. Varying methods of fixation, depending on the surgeon's preference and personal experience, did not appear to affect the positive clinical outcome of any case.

Our goal in presenting this research was to demonstrate that this cryopreserved, osteochondral allograft is 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. STI

## AUTHORS' DISCLOSURES

No funds were received in support of this study. No benefits in any form have been or will be received from a commercial party related to the subject of this study.

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