# Temporomandibular Joint Discectomy Followed by Disc Replacement Using Viable Osteochondral and Umbilical Cord Allografts Results in Improved Patient Outcomes

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**Purpose:** The ideal surgical solution to reconstruct the temporomandibular joint (TMJ) disc after it has been removed has remained elusive. The major obstacle has been identifying a durable biocompatible material that will provide for restoration of TMJ function. The present study evaluated the outcomes of the interpositional implantation of a cryopreserved viable osteochondral allograft (CVOCA) combined with a viable cryopreserved umbilical cord tissue (vCUT) allograft after TMJ discectomy in patients with internal derangement and/or degenerative joint disease (DJD).

**Patients and Methods:** We implemented a retrospective case series study and enrolled patients with DJD or disc displacement diagnosed using the Diagnostic Criteria of Temporomandibular Disorders, who had undergone interpositional CVOCA and vCUT implantation after TMJ discectomy. The primary outcome variable was pain, measured using a visual analog scale (VAS). The secondary outcomes variables included maximal incisal opening (MIO) and Glasgow Benefit Inventory (GBI) general subscale scores. The primary analysis compared the preoperative measures with those at the last follow-up visit. Descriptive and analytic statistics were computed to summarize the sample's characteristics and assess the pre- and postoperative differences.

**Results:** The study sample included 9 patients with a mean age of 36 years, and 44% were men. The VAS scores had decreased significantly from 9.0 ± 2.0 to 3.0 ± 3.0 postoperatively ($P$ = .001). The MIO had increased from 31 ± 5 to 36 ± 5 mm ($P$ = .178). The average GBI general subscale score of 13 ± 46 for the 9 patients showed a trend toward improved quality of life and patient satisfaction with the surgery. The median postoperative follow-up at the time of our report was 15 months (interquartile range, 10; range, 2 to 27) without treatment-related complications.

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Conflict of Interest Disclosures: S. Thaddeus Connelly is a paid speaker for Osiris Therapeutics, Inc. Alla Danilkovitch is a full-time employee of Osiris Therapeutics, Inc. None of the remaining authors have any relevant financial relationship(s) with a commercial interest.

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Received October 10 2018

Accepted May 31 2019



0278-2391/19/30555-5

https://doi.org/10.1016/j.joms.2019.05.024

**Conclusions:** The reported outcomes suggest that the interpositional implantation of CVOCA and vCUT after TMJ discectomy could be a solution for reducing TMJ-related pain and restoring TMJ function. Longer follow-up and prospective multicenter studies are warranted.

*J Oral Maxillofac Surg* ■*:1-12, 2019*

The complex musculoskeletal composition of the temporomandibular joint (TMJ) poses significant challenges to the surgical management of TMJ disorders once disc preservation is no longer feasible. Historically, TMJ discectomy has been indicated for an irreparable, deranged, or damaged disc. At present, TMJ discectomy is a common procedure with the longest follow-up data available among all the available treatments.[1,2] However, the data have remained limited to small studies without control groups, randomization, or blinding. Some surgeons have a strong perception that the replacement of the disc with appropriate biomaterial should be performed to reduce the severity of TMJ remodeling and improve the long-term outcomes after TMJ discectomy. Data from animal models have supported the benefits of replacing the TMJ disc with compatible biomaterials.[3]

The reported data are replete with case reports and case series of various techniques that used different materials to substitute for the TMJ disc, with varying degrees of reported success.[4-7] Alloplastic materials, such as the Teflon-Proplast implants, were used in the 1970s and 1980s. However, these implants were withdrawn from the market because of foreign body reactions and the development of severe inflammation, leading to bone erosion and destruction of the surrounding tissues.[4]

The use of autogenous grafts, such as pedicled flaps, ear cartilage, and dermis, has been reported in previous studies.[4-7] It has been shown that the use of free fat grafts can reduce fibrosis and heterotopic calcification; however, fat grafts become easily fragmented with rapid reduction of the implanted volume.[6] The use of abdominal dermis–fat grafts has overcome the limitations of free fat grafts. However, major concerns also exist for these grafts, including degeneration of the condyles after implantation and donor site morbidity associated with tissue harvesting.[7] Additionally, the attachment of an autogenous graft to either retrodiscal tissue remnants, the lateral pterygoid muscle, or the lateral pole of the condylar head is technically challenging and often unstable.[2]

To withstand the long-term compressive forces of the TMJ, the key requirements for reconstructive materials include biocompatibility with properties close to the native fibrocartilage, the ease of fixation against the mandibular fossa and articular eminence to provide a permanently immobilized surface for condyle head articulation, and support of the host's natural reparative process.[4] With advances in tissue preservation, different tissue allografts have become commercially available. Osteochondral allografts have been commonly used for the treatment of focal cartilage defects with good long-term outcomes and without rejection of the donor tissue.[8,9] Human placental tissue, in particular, the amniotic membrane, has been used in surgical procedures, including for treatment of the TMJ.[10-15] The low immunogenicity and anti-inflammatory, antifibrotic, and antibacterial properties of placental tissue have made it an attractive choice for biological grafts.[16-20]

An analysis of the structure and properties of the various allografts currently available on the market resulted in the identification of a cryopreserved viable osteochondral allograft (CVOCA) and a viable cryopreserved umbilical cord tissue (vCUT) allograft as optimal candidates to use as interpositional grafts. Animal and human data have shown that after implantation in a cartilage defect, CVOCA integrates with the host's remaining cartilage, leading to restoration of the articular cartilage.[21-25] vCUT is composed of amnion and a mucoid connective tissue known as Wharton's jelly.[26] Umbilical tissue has biological properties similar to that of the amniotic membrane but is thicker than the amniotic membrane and can be easily cut and sutured at a surgical site. Surgical implantation of vCUT in animals and patients led to the reduction of inflammation and prevention of postoperative adhesions, correlating with less pain and faster postoperative recovery.[26-31] No adverse reactions have been reported for the CVOCA and vCUT.

The purpose of the present study was to retrospectively evaluate the outcomes of the interpositional implantation of CVOCA combined with vCUT after TMJ discectomy in 12 patients who had presented with internal derangement and/or degenerative joint disease (DJD) for whom several other treatment options had failed. The specific aims of the present study included *1)* an assessment of the post-versus preoperative pain using a visual analog scale (VAS) as the primary study outcome; *2)* evaluation of the maximal incisal opening (MIO) as a measure of TMJ functionality; and *3)* calculation of the Glasgow Benefit Inventory (GBI) general subscale scores for

assessment of patient satisfaction with the surgical procedure.

## Patients and Methods

### STUDY DESIGN AND SAMPLE

To address the study purpose, we designed and implemented a retrospective case series. The study population included all patients who had presented with TMJ pain and dysfunction refractory to other treatments for evaluation and management at the San Francisco Veterans Affairs Medical Center from May 2016 to May 2018. To be included in the study sample, a diagnosis of DJD or disc displacement (DD) was required. The diagnosis was determined using the Diagnostic Criteria of Temporomandibular Disorders,[32] clinical examination findings, patient history, and preoperative imaging findings (noncontrast-enhanced computed tomography [CT] or magnetic resonance imaging [MRI] of the TMJ). In addition, the patients must have required surgical treatment with interpositional CVOCA and vCUT implantation after TMJ discectomy. In addition, the subjects must have had TMJ pain scores and functionality collected preoperatively and postoperatively from at least 1 follow-up visit and the postoperative quality of life score available. Subjects with incomplete data sets for TMJ pain, functionality, or quality of life were excluded from the present sample.

The surgical team for all cases consisted of 3 of us (S.T.C., R.S., R.J.G.). The results were independently evaluated by 1 of us (G.M.T.). Owing to the retrospective nature of the present study, the San Francisco VA Health Care System, University of California, San Francisco, institutional review board granted an exemption in writing regarding informed patient consent. The present study was conducted in compliance with the ethical rules outlined in the Declaration of Helsinki.

### STUDY VARIABLES

The independent variables included age, gender, diagnosis, surgical site, medical history of TMJ disorders, a list of concomitant treatments, and postoperative follow-up time. The dependent variables (outcomes) included postoperative TMJ pain, functionality, and quality of life scores.

The primary outcome variable of the present study was the postoperative level of pain compared with preoperatively, measured using a VAS. The VAS scores at the latest postoperative follow-up visit were compared with the preoperative baseline pain VAS scores. The VAS for pain was a continuous scale composed of a 10-cm horizontal line anchored by 2 verbal descriptors: "no pain" and "pain as bad as it could be." The VAS for pain was completed by the subjects. The subjects were instructed to place a line perpendicular to the VAS line at the point that represented their pain intensity. Using a ruler, the score was determined by measuring the distance on the 10-cm line between the "no pain" anchor and the subject's mark, with a range of scores from 0 to 10, and a higher score indicating greater pain intensity.

The secondary outcomes variables included post- versus preoperative TMJ functionality, measured by the MIO (in millimeters), and quality of life, measured using the GBI general subscale scores. To measure the MIO, the subjects were asked to open their mouth to the maximum without assistance until no further opening was possible with their head resting against a firm wall surface and in an upright position. The distance from the incisal edge of the upper incisor teeth to the incisal edge of the lower incisor teeth was measured using a calibrated fiber ruler, with the findings recorded in millimeters.

The GBI is a validated, postinterventional, patient-recorded outcome measure widely used in otolaryngology to evaluate the effect of the intervention on patients' quality of life.[33] The GBI questions are divided into 4 sections: general score, general subscale score, social support subscale, and physical health subscale. The general subscale measures patients' quality of life if the questions regarding social support and physical health are subtracted. The results range from −100 (maximum negative effect on quality of life) to +100 (maximum positive effect on quality of life).[33] The subjects were interviewed by telephone to complete the GBI. After the explanation and instructions, the subjects were asked to answer the 12 GBI general subscale questions. Each answer was graded with a score of 1 to 5, with 1 indicating the worst outcome and 5, the best.

### DATA COLLECTION AND STATISTICAL ANALYSIS

The present study was a retrospective nonrandomized case series. The patients' medical records were reviewed to obtain the necessary data. The data were collected retrospectively and de-identified, consistent with the terms and conditions outlined in the Health Insurance Portability and Accountability Act of 1996. All postoperative data included in the present analysis had been collected at the latest follow-up visit for each patient. The data were analyzed and are presented as the mean ± standard deviation, range, and 95% confidence intervals (CIs) for continuous variables and counts and percentages for categorical variables. The Wilcoxon test for paired data was used to determine the intragroup (pre- and postoperative) differences. The *t* test or Pearson correlation was used for bivariate analysis for the study variables and

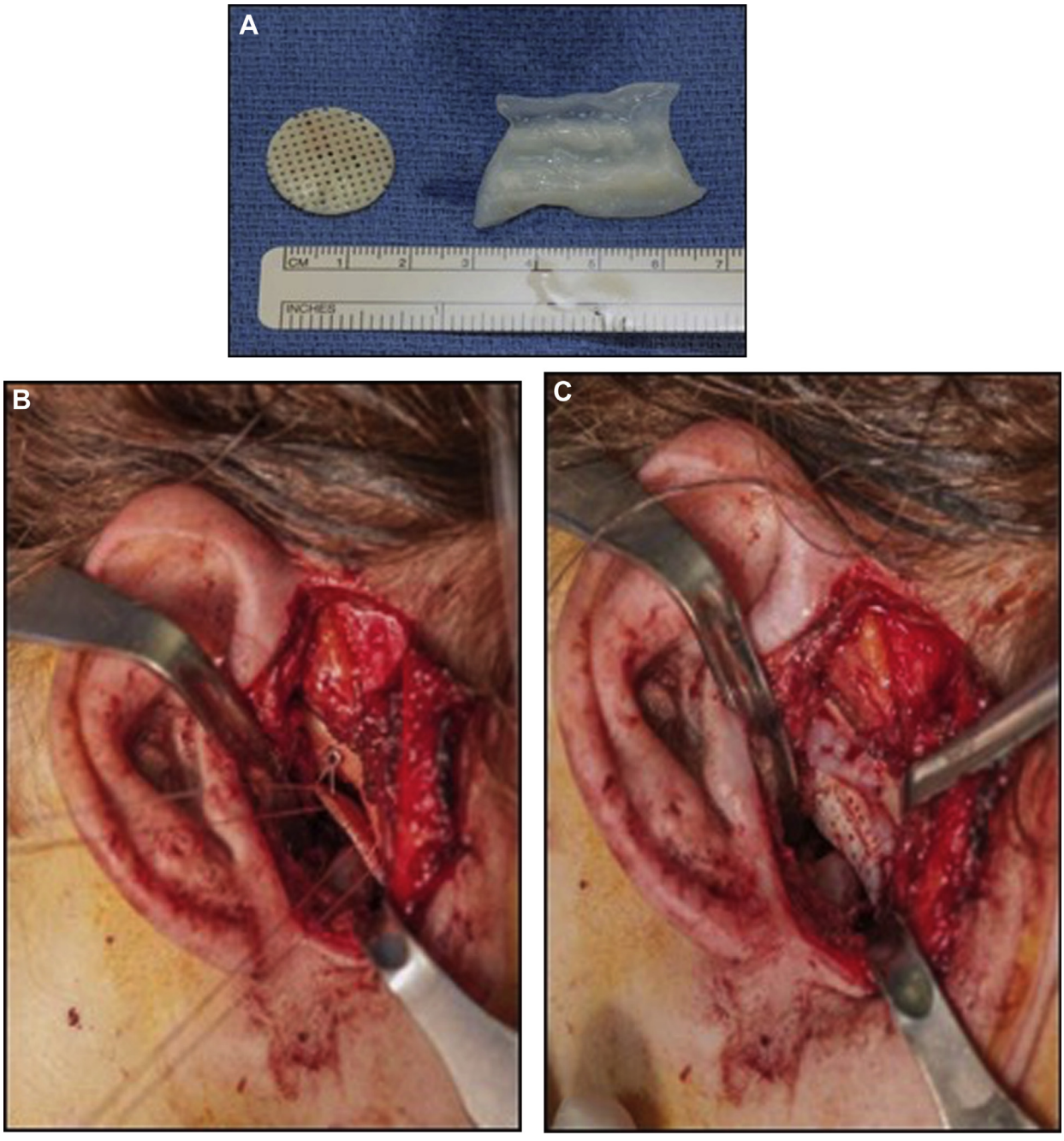


**FIGURE 1.** Interpositional implantation of cryopreserved viable osteochondral allograft (CVOCA) and viable cryopreserved umbilical cord tissue (vCUT) allografts after temporomandibular joint (TMJ) discectomy. *A,* Clinical appearance of 10-mm CVOCA disc (*Left*) and 2 × 4-cm vCUT (*Right*) grafts. Both grafts are flexible and easy to trim to fit the defect size and shape and anchor with sutures after implantation. *B,* Placement of CVOCA into the discectomized TMJ cavity and securing to remnants of the medial disc tissue with 3-0 FiberWire sutures (Arthrex Inc). *C,* After CVOCA implantation, the vCUT was placed in the superior joint space between the temporal bone and CVOCA. Microcorkscrew 4-0 FiberWire sutures (Arthrex Inc) were then passed through the pores of the CVOCA, securing the umbilical tissue allograft in place.

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the primary outcome. The hypothesis that the GBI scores would differ from 0 (with 0 indicating no changes) was tested using the *t* test for 1 population mean ($\alpha = 0.05$). The normal distribution of the data were verified using the Shapiro-Wilk test. Statistical significance was set at $P < .05$. JMP Statistical Discovery software (SAS Institute Inc, Cary, NC) was used for statistical analysis.

### CVOCA AND vCUT ALLOGRAFTS

CVOCA (Cartiform; Osiris Therapeutics, Inc, Columbia, MD; distributed by Arthrex, Naples, FL)

and vCUT (Stravix; Osiris Therapeutics, Inc) are processed from qualified eligible for transplantation tissue donors. The use of CVOCA and vCUT are regulated as a human cell, tissue and cellular and tissue-based product as defined in the US Food and Drug Administration 21CFR Part 1272 and Section 361 of the Public Health Service Act. Both CVOCA and vCUT allografts are processed aseptically in a controlled clean room environment, in accordance with rigorous quality assurance standards, and then stored and distributed for use in accordance with the regulations in 21 CFR 1271 and the standards of the American Association of Tissue Banks. CVOCA and vCUT must be stored in the original packaging at −75° to −85°C until used. Both products have a 2-year shelf life. CVOCA and vCUT retain extracellular matrix, growth factors, and viable cells native to the human cartilage and umbilical cord tissue, respectively.[21,26] The viable cells in human cartilage (chondrocytes and their precursors) and umbilical cord tissue (neonatal epithelial cells, fibroblasts, and mesenchymal stem cells) have low immunogenicity. Finally, these grafts do not require matching between donors and recipients.

### INTERPOSITIONAL CVOCA AND vCUT IMPLANTATION TECHNIQUE

The clinical appearance of a 10-mm CVOCA disc and a 2 × 4-cm vCUT graft are shown in Figure 1*A*. Both grafts are flexible, can be easily trimmed to fit the defect size and shape, and can be anchored with sutures on implantation. Before use, both grafts should be thawed using sterile saline solution according to the instructions outlined in their product inserts. Once the joint cavity has been carefully discectomized, the 10-mm CVOCA disc can trimmed as needed, passively fit into the cavity, and secured to remnants of the medial disc tissue with 3-0 FiberWire sutures (Arthrex Inc; Fig 1B). Next, the 2 × 4-cm vCUT should be trimmed as needed and placed in the superior joint space between the temporal bone and osteochondral allograft. Next, Micro Corkscrew suture anchors (Arthrex, Inc) are placed into the zygomatic arch above the joint space. The 4-0 FiberWire (Arthrex Inc) attached to the corkscrews is then passed through the pores of the CVOCA, securing both the cartilage and the umbilical tissue allografts up against the roof of the articular fossa (Fig 1C). Once good positioning and stability have been noted, the area should be copiously irrigated with 0.9% bacitracin-infused normal sterile saline solution. The preauricular surgical site is then closed using 3-0 and 4-0 Vicryl sutures (Ethicon, Somerville, NJ) for the deeper layers, 4-0 Monocryl sutures (Ethicon) for the deep dermal layer, and 5-0 fast-absorbing gut sutures for the skin and dressed in the normal procedural fashion.

**Table 1. ENROLLED SUBJECT CHARACTERISTICS**

| Study Variable | Descriptive Statistic |
|---|---|
| Sample size | 12 (100) |
| Male gender | 6 (50) |
| Age (yr) | 39 ± 13 |
| Diagnosis | |
| DJD | 6 (50) |
| DD | 6 (50) |
| Affected TMJ | |
| Unilateral | 8 (67) |
| Bilateral | 4 (34) |
| Preoperative VAS score for pain (n = 10) | 8 ± 2 |
| Preoperative MIO (mm) (n = 12) | 31 ± 8 |
| Postoperative follow-up (mo) | |
| Mean | 15 |
| Range | 2-27 |
| Median | 15 |
| Interquartile range | 10 |

*Note:* Data presented as n (%) or mean ± standard deviation, unless noted otherwise.

Abbreviations: DD, disc displacement; DJD, degenerative joint disease; MIO, maximal incisal opening; TMJ, temporomandibular joint; VAS, visual analog scale.

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### POSTOPERATIVE CARE PROTOCOL

All patients underwent a 3-week period of intermaxillary fixation (IMF) to prevent rotational or translational movement of the condyle against the newly implanted CVOCA–vCUT construct. After release of fixation at 3 weeks, all patients were placed into light guiding elastics for an additional 1 to 2 weeks and allowed to begin a nonchewing diet. Once all elastics had been discontinued and the IMF hardware had been removed, all the patients were scheduled for physical therapy to help regain jaw opening and given a manual jaw opening assisting device.

## Results

### STUDY SAMPLE

Of the 12 subjects enrolled in the present study, the final sample included 9 subjects with complete data sets available for pre- and postoperative TMJ pain and functionality and postoperative quality of life scores. Three patients with incomplete outcome variables were excluded from the analysis of outcomes. However, the treatment-related adverse events and complications were evaluated for all 12 enrolled patients.

The characteristics of the 12 enrolled subjects in the present study are summarized in Table 1. Twelve

**Table 2. STUDY SUBJECT CHARACTERISTICS***

| Pt. No. | Age (yr) | Gender | Surgery Side | Diagnosis | History of Trauma | Follow-up (months) | Concomitant Treatment | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Preoperatively | Postoperatively |
| 1 | 54 | Male | Right | DJD | No | 27 | Bilateral arthrocentesis, night guard, jaw exerciser device, intra-articular steroid injection | Botox, jaw exerciser device, physical therapy |
| | | | Left | | | 19 | Bilateral arthrocentesis, night guard, jaw exerciser device, intra-articular steroid injection | Botox, jaw exerciser device, physical therapy |
| 2 | 34 | Male | Left | DJD | No | 25 | Intra-articular steroid injection, Botox | Jaw exerciser device, Botox |
| 3 | 27 | Female | Right | DD WR IL | Yes, right jaw | 21 | Muscle relaxants, Botox, intra-articular steroid injection | Botox, jaw exerciser device, physical therapy |
| | | | Left | DD WR IL | | | | |
| 4 | 28 | Male | Left | DD WR NL | Yes, left TMJ | 21 | Botox, arthrocentesis, intra-articular steroid injection | Botox, intra-articular amniotic fluid injection, jaw exerciser device, physical therapy |
| 5 | 39 | Female | Left | DJD | No | 15 | Intra-articular steroid injection, Botox | Jaw exerciser device, Botox, physical therapy, intra-articular amniotic fluid injection |
| 6 | 47 | Male | Right | DJD | No | 15 | Arthrocentesis, intra-articular steroid injection, Botox | Jaw exerciser device, physical therapy |
| 7 | 44 | Female | Left | DJD | Yes, right side of face | 13 | Botox | Jaw exerciser device, Botox, physical therapy |
| | | | Right | DJD | | | | |
| 8 | 36 | Female | Right | DD WR NL | No | 12 | Right intra-articular steroid injection, Botox, orthodontic therapy, surgically assisted rapid palatal expansion, maxillary Le Fort I and mandibular bilateral sagittal split osteotomy, right intra-articular amniotic fluid injection, jaw exerciser device, physical therapy | Intra-articular amniotic fluid injection, jaw exerciser device, physical therapy |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 9 | 37 | Female | Left | DD WOR NL | No | 11 | Occlusal splint, Botox, intra-articular steroid injection, arthroscopy, intra-articular amniotic fluid injection | Jaw exerciser device, Botox, physical therapy |
| 10 | 67 | Male | Right | DJD | Yes, right orbital floor; no jaw trauma | 10 | Intra-articular steroid injection | Jaw exerciser device, physical therapy |
| 11 | 26 | Female | Right | DD WOR IL | No | 9 | Botox, night guard | Jaw exerciser device, Botox, intra-articular amniotic fluid injection, physical therapy |
| | | | Left | DD WR IL | | | | |
| 12 | 26 | Male | Right | DD WOR NL | Developed pain after extraction of wisdom teeth | 2 | Intra-articular steroid injection, Botox, occlusal splint | Jaw exerciser device, physical therapy |

Abbreviations: DD, disc displacement; DJD, degenerative joint disease; IL, intermittent locking; NL, no locking; Pt. No., patient number; TMJ, temporomandibular joint; VAS, visual analog scale; WOR, without reduction; WR, with reduction.

* Data collected between 3 (except for patient 12) and 12 months after discectomy and rounded to whole numbers.



patients (6 men; 50%) with a mean age of 39 ± 13 years and 16 affected TMJs had undergone interpositional CVOCA and vCUT implantation after TMJ discectomy. Before the surgery, multiple therapeutic lines, including steroids and Botox injections, night guards and occlusal splints, physiotherapy, and arthrocentesis, had failed. A complete summary of the failed therapies is provided in Table 2. Six patients (50%) had a diagnosis of DJD and 6 had a diagnosis of DD. Of the 6 cases of DD, 1 was reduction and intermittent locking, 2 were reduction without locking, 1 was without reduction but with intermittent locking, and 2 were without reduction and without locking (Table 2). The mean preoperative VAS pain score was 8.0 ± 2.0 (n = 10; 2 patients had no VAS score at baseline). The mean preoperative baseline MIO was 31 ± 8 mm (n = 11; patient 12 had only had 2 months of postoperative follow-up). A complete list of the clinical characteristics and pre- and postoperative concomitant treatments for each patient are summarized in Table 2. At the time of the present report, the average postoperative follow-up period was 15 ± 7 months (range, 2 to 27; median, 15; interquartile range, 10) No treatment-related complications were reported.

## OUTCOMES

The study outcomes for the study sample are summarized in Tables 3 to 5 and were collected at least 1 year postoperatively. Of the 12 patients, the 9 (mean age, 36 years; 44% male) with complete data sets were included in the study outcome analysis. No patient had withdrawn from the study.

### *Pain Analysis*

Postoperative pain was the primary endpoint of the present study. For the study cohort, the VAS scores had significantly decreased from 9.0 ± 2.0 preoperatively to 3.0 ± 3.0 postoperatively ($P$ = .001). The difference between the mean pre- and postoperative pain score was 6 (95% CI, 3.6 to 8.4; Table 3). Four patients had reported a preoperative VAS pain score of 10 (worst pain possible), 4 patients had reported very severe pain, and 1 patient had reported severe pain (Table 4). All 9 patients had reported a decrease in their pain postoperatively, including 5 with mild pain, 3 with moderate pain, and 1 with severe pain (Table 4). Only 1 patient reported an increase in pain postoperatively over time. This patient had had a decrease in pain from 10 preoperatively to 5 postoperatively but reported a pain increase from 5 to 8 "very severe" at the 15-month follow-up examination (Table 4). Bivariate analysis of the study variables compared with the primary outcome variable (pain) found no associations (Table 5).

**Table 3. SUMMARY OF KEY ENDPOINTS**

| Key Endpoint | Preoperative | Postoperative | Difference | 95% CI | *P* Value |
|---|---|---|---|---|---|
| VAS score for pain (n = 9) | 9 ± 2 | 3 ± 3 | 6 | 3.6 to 8.4 | .001* |
| MIO (n = 9) | 31 ± 5 | 36 ± 5 | 5 | −9.62 to −0.38 | .178* |
| GBI general subscale score (n = 9) | NR | 13 ± 46 | NA | −22 to 48 | .210† |

Abbreviations: CI, confidence interval; GBI, Glasgow Benefit Inventory; MIO, maximal incisal opening; NA, not applicable; VAS, visual analog scale.

* Wilcoxon test for paired data used to determine the intragroup (pre- and postoperative) differences.

† The hypothesis that the GBI scores differed from 0 was tested using the *t* test for 1 population mean ($\alpha = 0.05$); the normal distribution of the data was verified using the Shapiro-Wilk test, and statistical significance was set at $P < .05$.

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*MIO and GBI Analysis*

The mean MIO had increased from 31 ± 5 mm preoperatively to 36 ± 5 mm at the latest follow-up visit in the 9 patients. However, the improvement was not statistically significant ($P = .178$). The difference between the mean pre- and postoperative MIO was 5 (95% CI, −9.62 to −0.38; Table 3). The pre- and postoperative MIO values for each patient are listed in Table 4. Patient 12 was still recovering from surgery and had only preoperative MIO data at the time of the analysis.

The average GBI general subscale scores collected at the latest postoperative visit at the data analysis was 13 ± 46 (95% CI, −22 to 48; Table 3). The GBI general subscale scores for the individual patients are presented in Table 4. Seven patients reported that their quality of life had remained the same or had improved (Table 4). Two patients reported improvement close to the maximal possible improvement. Only 1 patient reported a significant decrease in quality of life (patient 5; Table 4). This same patient also had no improvement in the MIO (Table 4) and only transient pain reduction, with the pain level returning almost to the baseline level at 15 months postoperatively (Table 4). The test of the hypothesis that the GBI scores would differ from 0 failed to reject the null hypothesis (H0; $P = .210$).

## Discussion

The goal of the present single-center retrospective case series study was to evaluate the outcomes of

**Table 4. FUNCTIONAL OUTCOME OF SURGICAL INTERPOSITIONAL IMPLANTATION OF CVOCA AND VCUT ALLOGRAFTS AFTER TMJ DISCECTOMY FOR EACH PATIENT**

| | VAS Score for Pain | | MIO (mm) | | |
|---|---|---|---|---|---|
| Pt. No. | Preoperative | Postoperative | Preoperative | Postoperative | Postoperative GBI General Subscale Score |
| 1 | 10 | 3 | 38 | 35 | 0 |
| 2 | 7 | 2 | 30 | 45 | 13 |
| 3 | 6 | 1 | 30 | 40 | 79 |
| 4 | 9 | 4 | 25 | 39 | 4 |
| 5 | 10 | 8* | 32 | 26 | −71 |
| 6 | 10 | 1 | 25 | 37 | 33 |
| 7† | NA | NA | 10 | 31 | NA |
| 8 | 10 | 2 | 33 | 37 | 75 |
| 9 | 7 | 0 | 30 | 32 | 0 |
| 10† | NA | NA | 40 | 35 | NA |
| 11 | 6 | 5 | 40 | 36 | −13 |
| 12† | 9 | 4 | 30 | 45 | |

Abbreviations: CVOCA, cryopreserved viable osteochondral allograft; GBI, Glasgow Benefit Inventory; MIO, maximal incisal opening; NA, not available; Pt. No., patient number; TMJ, temporomandibular joint; VAS, visual analog scale; vCUT, viable cryopreserved umbilical cord tissue.

* Patient 5 had experienced a decrease in pain from a score of 10 preoperatively to 5 postoperatively (data not shown) but reported an increase in pain from a score of 5 to 8 at 15 months postoperatively.

† Patients 7, 10, and 12 had missing data and were excluded from the analysis of outcomes.

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**Table 5. BIVARIATE ASSOCIATION BETWEEN STUDY VARIABLES AND THE PRIMARY OUTCOME**

| Study Variable | VAS Score for Pain | *P* Value |
|---|---|---|
| Gender | | .809* |
| Male | 3 ± 1 (5) | |
| Female | 3 ± 3 (5) | |
| Age | 3 ± 2 (10) | .670† |
| Diagnosis | | .656* |
| DJD | 4 ± 3 (4) | |
| DD | 2 ± 2 (6) | |
| Affected TMJ | | .923* |
| Unilateral | 3 ± 3 (7) | |
| Bilateral | 3 ± 2 (3) | |
| Preoperative VAS score for pain | 3 ± 2 (10) | .442† |
| Preoperative MIO | 3 ± 2 (10) | .380† |
| Postoperative follow-up (mo) | 3 ± 2 (10) | .663† |

*Note:* Data presented as mean ± standard deviation (number of patients).

Abbreviations: DD, disc displacement; DJD, degenerative joint disease; MIO, maximal incisal opening; TMJ, temporomandibular joint; VAS, visual analog scale.

* *t* Test.

† Pearson correlation.

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the interpositional implantation of CVOCA and vCUT allografts after TMJ discectomy in patients presenting with DD or DJD. We hypothesized that interpositional implantation of a combination of placental and osteochondral allografts after TMJ discectomy might result in restoration of TMJ functionality without donor site morbidity. The specific aims included the following: *1)* a retrospective analysis of postoperative pain as a primary endpoint; and *2)* the MIO and GBI general subscale scores as secondary endpoints.

Our selection of CVOCA and vCUT allografts for TMJ surgery after discectomy was based on the positive clinical outcomes reported for placental membranes and osteochondral autografts for a broad variety of surgical reconstructive procedures. Case studies have reported positive outcomes for CVOCA implantation into focal cartilage defects in different locations in the knee, talar dome of the foot, and glenoid.[22-25] The integration of the CVOCA with the surrounding host cartilage after implantation over time has been shown in animals and patients.[21,22] The vCUT is cryopreserved umbilical tissue that retains all structural components of fresh umbilical cord tissue, including viable epithelial cells, fibroblasts, and mesenchymal stem cells native to the tissue.[26] The composition and properties of vCUT are similar to those of placental membranes. However, the vCUT is thicker than placental membrane and can be easily manipulated and sutured at the surgical site.[27-31] In a rabbit model, vCUT was shown to prevent the development of postoperative adhesions and support the natural wound healing process.[26] Clinical case studies have reported positive outcomes with the use of vCUT in the surgical repair of tendons, fistulas, and limb salvage.[27-31] To date, no CVOCA and vCUT-related adverse events have been reported.

Twelve patients with 16 painful refractory TMJs who had undergone CVOCA and vCUT implantation after TMJ discectomy at 1 center from May 2016 to May 2018 were enrolled in the present study. The study sample characteristics and the characteristics for each study subject are summarized in Tables 1 and 2, respectively. No treatment-related adverse events or complications were reported for the 12 patients enrolled in the present study. Of the 12 patients, the 9 with complete data sets were included in the study outcome analysis. Three patients were excluded from the study sample owing to incomplete data for outcome variables. The positive preliminary results of the present study have supported the safety and potential benefits of CVOCA and vCUT for TMJ reconstruction after discectomy. CVOCA and vCUT implantation after TMJ discectomy resulted in statistically significant postoperative pain reduction with improvement in the postoperative MIO and quality of life (Table 3).

Although the changes in the MIO and GBI scores showed a positive trend, the improvement in MIO did not reach statistical significance, and the null hypothesis H0 (GBI score, 0) could not be rejected. This could be attributed to the type II statistical error owing to the small sample size and/or the short postoperative follow-up time. We did not find an association between the study variables and the primary outcome (Table 3), which could also have resulted from the small sample size. No complications were recorded during the procedure or at the follow-up visits (range, 2 to 27). No graft removal or additional surgical procedures were required for any of the study patients.

Discectomy has been the most common surgery performed for painful TMJs and also has the most long-term outcomes data available. The reported data have demonstrated that TMJ discectomy without replacement can result in improvement of mobility and a reduction in pain.[1,2] Discectomy addresses the anatomic problems that lead to pain and reduced functionality. However, it cannot result in tissue regeneration. It has been shown that discectomy followed by no replacement can trigger crepitus and radiographic evidence of osteophytes, flattening, and sclerosis.[1] Although such changes have been considered adaptive, rather than destructive, remodeling, concern exists that these changes could encourage the escalation of the degenerative process.

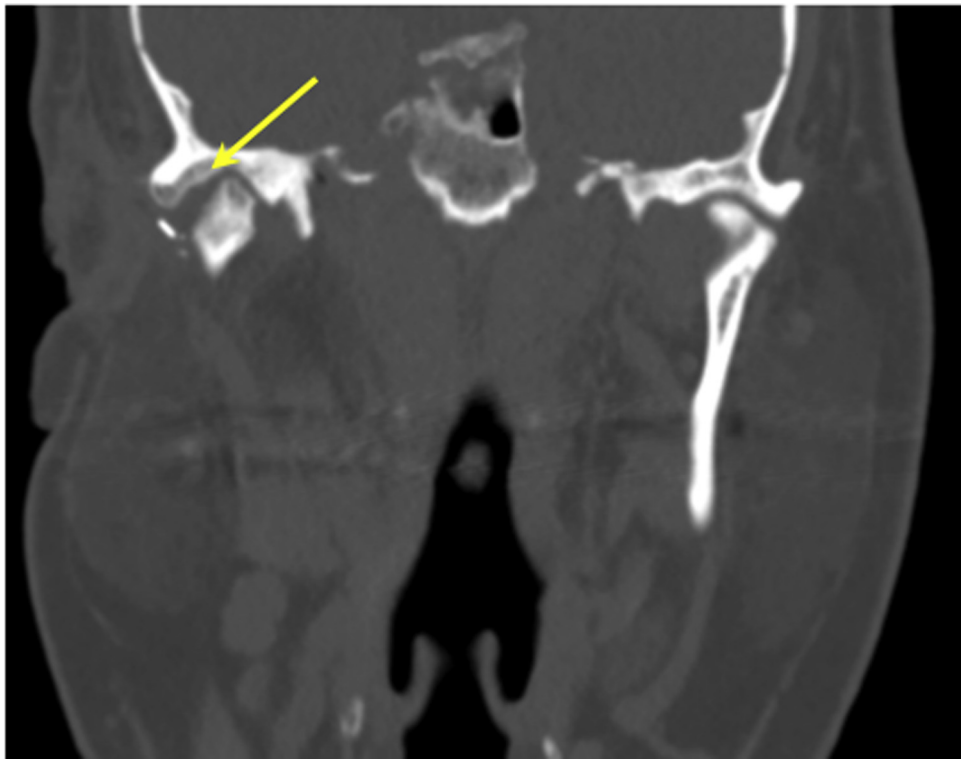

**FIGURE 2.** Postoperative computed tomography coronal image of a 47-year-old male patient with a diagnosis of right temporomandibular joint degenerative joint disease showing tissue regeneration (*arrow*) in the area of the glenoid fossa ~17 months postoperatively.

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Various autografts from different anatomic locations such as costal cartilage, auricular cartilage, dermis, fat, dermis–fat, fascia, and temporal muscle have been used with mixed results.[4] Dimitroulis[34] reported the results of a retrospective study of 28 patients who had undergone TMJ discectomy with an interpositional abdominal dermis–fat graft for the management of severe internal derangement. Their results indicated that the interpositional dermis–fat graft failed to prevent significant condylar changes in ~70% of the patients.[34]

Svensson et al[35] reported a retrospective analysis of auricular cartilage grafting in TMJ arthroplasty. Eighteen patients with 23 affected TMJs were included in their analysis. In 16 joints, pain had been reduced significantly from an average score of 8 to 4, and the MIO had improved from 28 to 35 mm. However, 3 of the grafts had to be removed from 7 TMJs in 6 patients at mean of 26 months (range, 9 to 50) after surgery.[35] Fibrous adhesions and fragmentation of the cartilage grafts were reasons for graft removal, consistent with previous reports. The harvesting of the auricular grafts was also associated with the creation of tissue loss at the donor sites. Other studies have reported a wide spectrum of results for auricular grafts, ranging from good (85 to 90% patients reporting reduced pain) to significantly less favorable (63% of patients reporting persistent pain).[5,36] Although discectomy and auricular cartilage interposition graft is an acceptable method for refractory TMJ dysfunction, a high failure rate and progressive degenerative changes in the joint suggest it would be wise to consider other approaches.[37,38]

Bone (metatarsal or sternoclavicular) or osteochondral grafts have also been frequently used as interpositional materials.[39,40] It has been shown that an autologous osteochondral autograft combined with a free-fat graft will result in better outcomes compared with other graft materials. However, the potentially uncontrollable bone growth and donor site morbidity are serious drawbacks of the autologous osteochondral graft.[40]

In discectomy cases, the temporalis myofascial flap can succeed in providing a significant amount of tissue over the native condylar head. However, problems with tissue thickness and donor site morbidity, including pain, restricted mouth opening, and cosmetic deformities, have precluded its use in many cases.[41] In general, pedicled flap techniques will often be unnecessarily invasive and complex when the case only requires an interpositional material to replace the temporomandibular disc.

Reported studies have described the successful use of placental amnion for oral and maxillofacial surgery

in intraoral and extraoral lining.[42] Freeze-dried gamma-radiated amnion was used in 13 patients with unilateral and bilateral bony TMJ ankylosis. The amnion was folded to form a cap consisting of 10 to 15 layers. Next, the "amniotic cap" was placed over the condylar head and anchored to the surrounding tissues. The interincisal opening had improved postoperatively, and no significant reduction was found in the interincisal opening at 5 years postoperataively.[43] In 2013, the successful use of amnion combined with a costochondral graft as an interpositional material in TMJ reconstruction was described in a case report.[44] The most recent case report described the implantation of a cryopreserved amniotic patch as a disc-replacing graft after TMJ discectomy in a 48-year-old woman with TMJ DD.[15] At 3 months postoperatively, she had reported no pain and overall improvement. The investigators concluded that the results were encouraging and that the use of the placental tissue should be considered in the treatment of TMJ disease.[15]

Overall, the number of studies using interpositional tissue grafts for TMJ reconstructive procedures has been low. The high heterogenicity in patient populations, types of grafts used, and surgical techniques have made it difficult to draw comparisons among the reported studies.

The clinical outcomes in the present study were similar to previously reported data for TMJ discectomy without replacement and the use of autologous tissues as an interpositional disc replacement. However, the use of CVOCA and vCUT eliminates the need for tissue harvesting and the morbidity associated with the donor tissue site. Avoiding an autogenous tissue harvesting procedure, in addition to the ease of CVOCA and vCUT implantation, can significantly reduce the duration of surgery. We also believe that the key advantage of the CVOCA and vCUT compared with discectomy without replacement is the potential to induce tissue regeneration. When CT or MRI studies were available, the postoperative images showed a remodeling of the condylar head with subsequent recortication of the condylar head with the establishment of de novo tissue on the glenoid fossa at ~12 to 18 months postoperatively (Fig 2). These preliminary findings suggest that perhaps CVOCA and vCUT stimulated such tissue regeneration. During the follow-up period, no graft failure, complications, or the requirement for additional surgical interventions were recorded.

In conclusion, the CVOCA and vCUT implantation technique is straightforward and reproducible, avoids donor site morbidity, and results in functional restoration of the TMJ without complications. The main strength of the present study was the first demonstration of tissue allograft utility for TMJ reconstruction. Another strength of the present study was the use of the GBI general subset score to measure patient satisfaction with the TMJ surgical procedure. The limitations of the study included its retrospective nature and a potential type II statistical error owing to the small number of patients. The postoperative VAS scores, MIO, and GBI general subscale scores were not collected for all patients, and the postoperative VAS, MIO, and GBI data were collected at least 1 year postoperatively for each patient. The present study lacked a comparator group and had a relatively short follow-up time. The reported outcomes of the present case series study suggest that the interpositional implantation of CVOCA and vCUT after TMJ discectomy could be a successful option for reducing TMJ-related pain and restoring TMJ function in selected patients. Longer follow-up and prospective multicenter studies are warranted for validation of this technique for functional TMJ reconstruction.

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