High Failure Rate of a Decellularized Osteochondral Allograft for the Treatment of Cartilage Lesions
Jack Farr, Guilherme C. Gracitelli, Nehal Shah, Eric Y. Chang and Andreas H. Gomoll
DOI: 10.1177/0363546516645086
The online version of this article can be found at:
http://ajs.sagepub.com/content/44/8/2015

Published by:
SAGE
http://www.sagepublications.com
On behalf of:
American Orthopaedic Society for Sports Medicine
ACSSM

Additional services and information for The American Journal of Sports Medicine can be found at:
Email Alerts: http://ajs.sagepub.com/cgi/alerts
Subscriptions: http://ajs.sagepub.com/subscriptions
Reprints: http://www.sagepub.com/journalsReprints.nav
Permissions: http://www.sagepub.com/journalsPermissions.nav

>> Version of Record - Aug 1, 2016
OnlineFirst Version of Record - May 13, 2016
What is This?
High Failure Rate of a Decellularized Osteochondral Allograft for the Treatment of Cartilage Lesions

Jack Farr,*† MD, Guilherme C. Gracitelli,‡ MD, Nehal Shah,§ MD, Eric Y. Chang,‖ MD, and Andreas H. Gomoll,§ MD
Investigation performed at OrthoIndy Hospital, Indianapolis, Indiana, USA, and Brigham and Women’s Hospital, Harvard Medical School, Boston, Massachusetts, USA

Background: Widespread adoption of fresh allograft transplantation remains limited, predominantly by supply issues. To overcome these limitations, a preshaped, cylindrical sterilized and decellularized osteochondral allograft (SDOCA) implant was recently introduced as a clinical treatment option.

Purpose: To evaluate functional outcomes and graft survivorship among patients treated with the SDOCA implant for knee cartilage injuries.

Study Design: Case series; Level of evidence, 4.

Methods: An institutional review board–approved database was used to identify a series of patients with prospectively collected data who had been treated with the SDOCA implant. The surgeries were performed at 2 centers by 2 surgeons. Patient-reported outcomes, magnetic resonance imaging (MRI), and the number and type of reoperations were assessed. Failure was defined as structural damage of the graft diagnosed by arthroscopy or MRI, and any reoperation resulting in removal of the allograft. Patients were evaluated pre- and postoperatively using the Knee injury and Osteoarthritis Outcome Score (KOOS) and Marx Sports Activity Scale. MRI was assessed preoperatively and postoperatively.

Results: There were 32 patients with a mean age (±SD) of 35.1 ± 10.6 years; 59% were male. Twenty-three (72%) knees had previous surgery. The mean defect area (±SD) was 2.9 ± 2.0 cm², and the mean allograft size was 13.18 ± 2.3 mm (6 grafts ≤9 mm and 59 grafts ≥11 mm). The median number of allografts per knee was 2 (range, 1-5 grafts). Twenty-three of the 32 knees (72%) were considered failures by the definition detailed above. Of these, 14 knees (43%) had further surgery after the index procedure. Implant survivorship was 19.6% at 2 years. The mean follow-up duration was 1.29 years (range, 0.11-2.8 years). KOOS pain, activities of daily living (ADL), sports and recreation (sport/rec), and knee-related quality of life improved significantly from the preoperative visit to latest follow-up. Age was significantly predictive of failure, with a hazard ratio of 1.68 per 1 SD older (95% CI, 1.05-2.68; P = .030). The MOCART (magnetic resonance observation of cartilage repair tissue) feature effusion was the only score to correlate with KOOS (symptoms, pain, ADL, sport/rec).

Conclusion: The SDOCA implant demonstrated a 72% failure rate within the first 2 years of implantation at these 2 institutions.

Keywords: cartilage; osteochondral allograft; osteochondral defect; osteochondral transplantation

Chondral and osteochondral defects still represent a treatment challenge to orthopaedic surgeons, especially in cases of larger defects associated with subchondral bone abnormalities.3,6 Since 1998, when fresh osteochondral allografts first became commercially available in the United States (rather than through hospital tissue banks), their use as a surgical option for cartilage repair has steadily increased.3,6,20 However, even more widespread adoption of fresh allograft transplantation remains limited predominantly by supply issues: Only young donors with intact joint surfaces can be considered for harvesting, many grafts fail biological testing, and there is a short window of generally 28 days between harvest and implantation before chondrocyte viability starts to decrease. As a result of these limitations, tissue banks report up to 80% of retrieved grafts are wasted (personal communication with tissue banks).

To overcome the limitations of allograft availability and to extend shelf life, the preshaped, cylindrical sterilized and decellularized osteochondral allograft (SDOCA) implant (Chondrofix; ZimmerBiomet) was recently introduced as a clinical treatment option. The graft undergoes a process involving lipid extraction and ultraviolet light–mediated viral inactivation in a methylene blue solution, which is responsible for its unique blue-green appearance.5 It is packaged and then terminally sterilized with radiation. Given its acellular nature, eventual failure was a likely outcome, although the time frame was unknown as the only
study before release was an 18-month equine study (unpublished in-house study at ZimmerBiomet reported at AOSSM 2015) that demonstrated smooth cartilage surfaces, intact matrix, complete bony integration, and no bone cysts. Therefore, the implant has been positioned as a bridging solution before other surgical procedures such as fresh osteochondral allograft transplantation or arthroplasty.

To date, no study has analyzed the clinical and radiological outcomes of SDOCA in the treatment of symptomatic osteochondral defects. We present a multicenter prospective cohort study evaluating functional outcomes, graft survivorship, and radiological analysis among patients treated with this implant for cartilage injuries in the knee.

METHODS

Indications

Our centers prospectively collect data on all cartilage transplant patients. Following institutional review board approval, we identified all patients treated with the SDOCA implant. Among these patients, 1 subset (22 patients) was treated as part of a prospective clinical trial sponsored by Zimmer according to a pre-established clinical protocol (ClinicalTrials.gov [Identifier: NCT1410136]), while the remaining patients (10 patients) were treated outside the study as part of clinical practice. The main inclusion criteria did not differ significantly between on- and off-study patients: male and nonpregnant female subjects between 18 and 70 years; up to 2 full-thickness (Outerbridge grades 3 and 4; International Cartilage Repair Society [ICRS] grades 3 and 4) cartilage lesions of the knee, each measuring <8 cm²; and localized knee pain unresponsive to nonoperative treatment (eg, medication, bracing, physical therapy) and/or previous surgical intervention. The exclusion criteria were cartilage lesion location such that the implanted graft(s) would not be adequately shouldered; bipolar articular cartilage involvement (or kissing lesions) of the ipsilateral compartment (ie, ICRS grade 2 on the opposing articular surface); septic or reactive arthritis or systemic disease (eg, rheumatoid arthritis, gout, or prior history of gout or pseudo-gout); sickle cell disease, hemochromatosis, or autoimmune disease; and deficiency limiting ability to perform an objective functional assessment of the operative knee or an inability to adhere to a postoperative rehabilitation protocol.

Surgical Technique

The surgical technique employed depended on plug size. For 7-, 9-, and 11-mm plugs, an all-arthroscopic approach was available, similar to an osteochondral autograft transfer (OAT) technique. However, the majority of procedures were performed in a mini-open approach for better visualization and accurate plug placement. After adequate exposure, the defect was sized. A corresponding punch was placed perpendicular to the articular surface and impacted to the desired depth to exactly match the plug dimension; generally, the premade plug length measured approximately 10 mm (Figure 1A). Then, the punch was removed and the depth verified with the sizing rod (Figure 1B). The implant was introduced into a holding device (Figure 1C) and inserted until fully flush with the surrounding cartilage using an oversized tamp with manual pressure or light tapping (Figure 1D).

Figure 1. SDOCA implant surgical technique employed for 7-, 9-, and 11-mm plugs. (A and B) The defect was sized, and a punch was used in a perpendicular fashion to create a recipient slot. (C) The implant was introduced in a holding device. (D) Final aspect of the implant after insertion. SDOCA, sterilized and decellularized osteochondral allograft.

*Address correspondence to Jack Farr, MD, OrthoIndy Cartilage Restoration Center of Indiana, 1260 Innovation Parkway, Suite 100, Greenwood, IN 46143, USA (email: jfarr@orthoindy.com).
1Cartilage Restoration Center of Indiana, OrthoIndy Hospital, Indianapolis, Indiana, USA.
2Department of Orthopaedic Surgery, Federal University of São Paulo, São Paulo, Brazil.
3Brigham and Women’s Hospital, Harvard Medical School, Boston, Massachusetts, USA.
4Radiology Service, VA San Diego Healthcare System, San Diego, California, USA.

Presented at the 41st annual meeting of the AOSSM, Orlando, Florida, July 2015.

One or more of the authors has declared the following potential conflict of interest or source of funding: J.F. reports personal fees from Advanced Biosurfaces, Arthrex Inc, Arthrocare, BioRegeneration Technologies, Ceterix Orthopaedics, DePuy, Genzyme, Knee Creations LLC, MedShape Inc, Mitek, Moximed Inc, NuOrtho Surgical Inc, NuTech Medical, Osiris Therapeutics Inc, RTI Biologics Inc, Schwartz Biomedical LLC, Science and Biomaterials Inc, Springer, Stryker, Thieme Medical Publishers Inc, and ZimmerBiomet; and nonfinancial support from Arthrocare, DePuy, DePuy/Mitek, Genzyme, Histogenics, Knee Creation Inc, Moximed Inc, NuTech Medical, RTI Biologics Inc, and ZimmerBiomet. A.H.G. reports grants and personal fees from Science for Biomaterials (SBM) and personal fees from Vericel, Geistlich, Aesculap, Regentis, Cartiheal, and NuTech, outside the submitted work.
For the 15-mm diameter plug size, a mini-arthrotomy was employed analogous to the standard technique for fresh osteochondral allograft transplantation.5 Once the cartilage defect was exposed, a 15-mm cannulated sizing guide was placed on the defect perpendicular to the articular surface. A guide pin was drilled through the central hole. The sizing guide was removed and a cannulated reamer used to prepare the defect to approximately 10-mm depth under cold irrigation to avoid thermal damage. The plug was delivered with the holding device and gently seated flush using the oversized tamp (Figure 2). When required, multiple plugs were most often seated edge-to-edge but, on occasion, were overlapped.

Postoperative Rehabilitation

The rehabilitation protocol was based on the number of plugs used. With single plugs, patients were encouraged to bear weight as tolerated and generally discontinued crutches within 2 to 4 weeks. With multiple plugs, partial weightbearing was recommended for at least 6 weeks. Range of motion was encouraged without restrictions, and stationary biking was started as soon as swelling and pain allowed. Weightbearing exercises were delayed for at least 6 weeks.

Follow-up Investigations

All patients were followed according to a predefined protocol. All subsequent surgeries were recorded. Clinical and functional scores were collected preoperatively and postoperatively with the Knee injury and Osteoarthritis Outcome Score (KOOS)19 and the Marx activity scale.13 On-study patients were imaged postoperatively according to a standardized protocol at 1.5, 3, 6, 12, and 24 months. Magnetic resonance imaging (MRI) was performed at 1.5, 12, and 24 months. Off-study patients were imaged postoperatively based on clinical need.

Failure of the procedure was defined as (1) any reoperation resulting in removal of the implant, such as revision with fresh osteochondral allograft transplantation or arthroplasty, and/or (2) when MRI or arthroscopy showed evidence of subchondral collapse or loss of more than 50% of the articular cartilage cap of a plug.

A standard musculoskeletal imaging protocol was followed. Imaging was performed on 1.5-T Magnetom Avanto systems (Siemens) with a knee coil. Two fellowship-trained musculoskeletal radiologists from separate institutions, with 4 and 6 years of experience, respectively, independently assessed the implants using the MOCART (magnetic resonance observation of cartilage repair tissue) score.12 Clinical and radiological correlation analysis was performed.

Our standard musculoskeletal protocol incorporated the following sequences: sagittal fast spin-echo (FSE) intermediate-weighted (repetition time/echo time [TR/TE], 2900/23 ms; echo train length [ETL], 8; 3-mm slice thickness [ST]; 1-mm gap; 384 × 269 matrix; 15-cm field of view [FOV]; and 1 signal average [SA]), sagittal FSE intermediate-weighted with fat suppression (TR/TE, 3050/39 ms; ETL of 8; 3-mm ST; 1-mm gap; 256 × 256 matrix; 15-cm FOV; 2 SA), sagittal FSE T2-weighted (TR/TE, 4510/79 ms; ETL of 11; 3-mm ST; 1-mm gap; 256 × 256 matrix; 15-cm FOV; 1 SA), coronal FSE intermediate-weighted (TR/TE, 2570/23 ms; ETL of 7; 3-mm ST; 1-mm gap; 384 × 256 matrix; 15-cm FOV; 1 SA), coronal FSE intermediate-weighted with fat suppression (TR/TE, 3500/44 ms; ETL of 8; 3-mm ST; 1-mm gap; 256 × 256 matrix; 15-cm FOV; 1 SA), coronal FSE T2-weighted (TR/TE, 4130/79 ms; ETL of 10; 3-mm ST; 1-mm gap; 256 × 256 matrix; 15-cm FOV; 1 SA), and axial FSE T1-weighted (TR/TE, 647/13 ms; ETL of 1; 3-mm ST; 1-mm gap; 256 × 256 matrix; 15-cm FOV; 1 SA), axial FSE T2-weighted with fat suppression (TR/TE, 5280/79 ms; ETL of 10; 3-mm ST; 1-mm gap; 256 × 256 matrix; 15-cm FOV; 1 SA), and axial FSE T2-weighted with fat suppression (TR/TE, 5280/79 ms; ETL of 10; 3-mm ST; 1-mm gap; 256 × 256 matrix; 15-cm FOV; 1 SA).

Tissue obtained during a revision procedure was independently histologically analyzed. Two 9-mm plugs were retrieved by using a 10-mm coring chisel (OATS system; Arthrex) to completely remove the entire plug to a depth of 12 mm. The tissue was stabilized in formalin and then

Figure 2. The surgical technique employed for 15-mm plug. (A) Mini-arthrotomy to assess the chondral defect. (B) A guide pin was drilled perpendicular to the articular surface through the cannulated sizer, and the defect was prepared with the reamer. (C) Appearance of the prepared defect ready for implantation. (D) The final appearance after insertion of the SDOCA implant. SDOCA, sterilized and decellularized osteochondral allograft.
decalcified and stained per standard protocol with hematoxylin and eosin and toluidine blue.

Statistical Analysis

Means and frequencies were used to report demographic data, details regarding the graft, and number and type of subsequent surgeries after SDOCA implantation. The Kaplan-Meier method was used to calculate survivorship with graft failure as the endpoint. The time to failure was defined by MRI or arthroscopic/open surgery, whichever came first. In the event that MRI results were inconclusive or doubtful, the time to surgery was used. The Wilcoxon signed-rank test was used to assess change from preoperative to latest follow-up for the KOOS and Marx scores. Mann-Whitney U tests were performed to compare mean of subgroup analysis (failed vs nonfailed group; study vs nonstudy group). A P value of .05 was used to determine statistical significance.

The MRI statistical analysis calculated interobserver variability of the MOCART classification system and the correlation of clinical outcomes (KOOS and Marx) with MOCART scores. Interobserver agreement was assessed using Cohen κ coefficients for the MOCART individual features and intraclass correlation coefficients for the MOCART total scores. Cohen κ coefficient and intraclass correlation coefficient range from 0 (no agreement) to 1.0 (complete agreement). The intermediate values were interpreted as follows: 0 to 0.2, slight agreement; 0.21 to 0.4, fair agreement; 0.41 to 0.6, moderate agreement; 0.61 to 0.8, substantial agreement; 0.81 to 1.0, superior agreement. Spearman correlation coefficients were used to assess correlation between standardized clinical questionnaires (KOOS and Marx) and the MOCART total scores. For individual features of the MOCART, Mann-Whitney U tests were performed to compare mean KOOS and Marx scores (absence vs presence of each feature). All variables of MOCART were characterized as normal findings or abnormal findings for analysis purposes. STATA software was used for all analyses (release 13; StataCorp LP).

RESULTS

Thirty-four patients were treated at our centers with the SDOCA implant. Two patients (2 knees) were lost to follow-up (1 at each center); therefore, complete data sets for 32 patients were available for the study (94% follow-up). Patients’ demographic data and allograft details are presented in Table 1. Twenty-three patients (72%) had

| TABLE 1: Patient Characteristics and Cartilage Details (N = 32 knees) |
|-------------------------|-------------------------|
| Age, mean ± SD, y       | 35.1 ± 10.6             |
| Sex, n (%)              |                         |
| Male                    | 19 (59.3)               |
| Female                  | 13 (40.6)               |
| Body mass index, mean ± SD, kg/m² | 27.7 ± 4.4          |
| Lesion location, n (%)  |                         |
| Medial femoral condyle  | 23 (57.5)               |
| Trochlea                | 8 (20)                  |
| Lateral femoral condyle | 6 (15)                  |
| Patella                 | 3 (7.5)                 |
| Defect size, mean ± SD (range), cm² | 2.9 ± 2.0 (0.9-8.75) |
| Previous surgery on affected joint, n (%) | 23 (71.8)         |
| No. of grafts, n (%)    | 65 (100)                |
| 1                       | 9 (13.8)                |
| 2                       | 16 (49.2)               |
| 3                       | 5 (23.0)                |
| 4                       | 1 (6.1)                 |
| 5                       | 1 (7.6)                 |
| Graft size, n (%), mm   |                         |
| 7                       | 1 (1.5)                 |
| 9                       | 5 (7.6)                 |
| 11                      | 20 (30.7)               |
| 15                      | 39 (60)                 |

*Some knees had more than 1 defect, and multiple allografts were implanted.
previous surgeries; 13 (41%) of these were of the articular cartilage (see the Appendix, available in the online version of this article and at http://ajsm.sagepub.com/supplemental). Nine patients had no previous surgery related to the knee joint.

Twenty-three of the 32 knees (72%) were considered treatment failures, with an average follow-up duration of 1.29 years (range, 0.11-2.8 years) (Figure 3). Two-year Kaplan-Meier survivorship of the SDOCA implant was 19.6% (Figure 4).

Of the 23 failures, 11 (34%) were diagnosed first as MRI failures (Figures 5 and 6), and 12 (38%) were considered failures only after arthroscopy or open surgery. Fourteen of the 32 knees (44%) had further surgery after the index procedure (Figures 7 and 8).

Of the 23 patients who previously underwent some form of surgical treatment, 18 (78.2%) were considered failures. Nine patients had SDOCA as their first surgical treatment, and 5 (55.5%) were considered failures. No significant difference between these groups was found ($P = .197$).

Twenty-two patients were included in the formal product study, 16 (72.7%) of whom were considered failures. The other 10 patients were treated outside the study, and 7 (70%) were considered failures. There was no significant difference between groups ($P = .595$).
Scores on the KOOS subscales for pain, activities of daily living (ADL), sports and recreation (sport/rec), and knee-related quality of life (QOL) improved significantly from the preoperative visit to latest follow-up (Table 2).

Table 3 shows a subgroup analysis of functional outcomes between the failure and nonfailure groups. We found statistically significant differences in postoperative scores at the latest follow-up in KOOS symptoms ($P = .008$), ADL ($P = .03$), and QOL ($P = .02$). Between groups, the change from preoperative to latest follow-up showed a significant difference (Table 3). A subgroups analysis of 9 patients treated solely for isolated chondral lesion without previous surgery showed statistically significant differences in postoperative scores at the latest follow-up in KOOS pain ($P = .04$) and ADL ($P = .01$).

Subanalysis demonstrated age as a significant predictor of failure with a hazard ratio of 1.68 per 1 SD older than the mean (95% CI, 1.05-2.68; $P = .030$). Defect size was not predictive of failure ($P = .184$). Defect size correlated with age, with a hazard ratio of 1.71 per 1 SD older than the mean (95% CI, 1.06-2.74; $P = .026$).

The interobserver agreement between the 2 examiners on individual features of the MOCART was at least substantial in 72% of comparisons (Table 4). In the analysis of observer 1, the feature effusion (MOCART score) was the only one to correlate with KOOS symptoms ($P = .060$, $P = .008$), ADL ($P = .56$, $P = .014$), and sport/rec ($P = .45$, $P = .047$). In the analysis of observer 2, the feature effusion (MOCART score) was the only one to correlate with KOOS symptoms ($P = .60$, $P = .008$), pain ($P = .51$, $P = .024$), and ADL ($P = .56$, $P = .014$).

The histological analysis of 2 plugs retrieved during revision with osteochondral allograft demonstrated the following findings:

- Other than the marrow space, the tissue had very few cells present. The majority of the cartilage was devoid of cells in both samples (Figure 9A).

### Table 2

<table>
<thead>
<tr>
<th>Measure</th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>KOOS Symptoms</td>
<td>54.5 ± 15.7</td>
<td>62.6 ± 20.6</td>
<td>.19</td>
</tr>
<tr>
<td>Pain</td>
<td>49.2 ± 14.1</td>
<td>62.2 ± 21.1</td>
<td>.01</td>
</tr>
<tr>
<td>ADL</td>
<td>57.9 ± 15.8</td>
<td>72.5 ± 17.9</td>
<td>.003</td>
</tr>
<tr>
<td>Sport/rec</td>
<td>19.2 ± 17.6</td>
<td>32.8 ± 25.8</td>
<td>.01</td>
</tr>
<tr>
<td>QOL</td>
<td>20.6 ± 19.1</td>
<td>34.6 ± 25.8</td>
<td>.01</td>
</tr>
<tr>
<td>Marx Sports</td>
<td>3.7 ± 5.4</td>
<td>1.6 ± 3.3</td>
<td>.13</td>
</tr>
</tbody>
</table>

*Values are reported as mean ± SD. ADL, activities of daily living; KOOS, Knee injury and Osteoarthritis Outcome Score; QOL, knee-related quality of life; Sport/rec, sport and recreation.*

### Table 3

<table>
<thead>
<tr>
<th>Measure</th>
<th>Nonfailure Group</th>
<th>Failure Group</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td>Postoperative</td>
<td>Difference</td>
<td>Preoperative</td>
</tr>
</tbody>
</table>

*Values are reported as mean ± SD. ADL, activities of daily living; KOOS, Knee injury and Osteoarthritis Outcome Score; QOL, knee-related quality of life; Sport/rec, sport and recreation.*

$P$ value for Mann-Whitney $U$ test to compare difference scores between groups (change from preoperative state to latest follow-up).
TABLE 4
Interobserver Agreement of Radiological Analysis: Descriptor, Coefficient Range, and Percentage of Comparisons for Each Descriptor

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>Coefficient (x) Range</th>
<th>Percentage of Comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior</td>
<td>0.81-1.0</td>
<td>29</td>
</tr>
<tr>
<td>Substantial</td>
<td>0.61-0.8</td>
<td>43</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.41-0.6</td>
<td>0</td>
</tr>
<tr>
<td>Fair</td>
<td>0.21-0.4</td>
<td>0</td>
</tr>
<tr>
<td>Slight</td>
<td>0-0.2</td>
<td>29</td>
</tr>
</tbody>
</table>

Figure 9. Histological analysis of 2 SDOCA implants after failure. (A) Partially delaminated implant showing area with residual cartilage cap. The cartilage is devoid of cells, while the marrow cavity is cellular. (B) The subchondral bone shows areas of empty lacunae and others with viable cells. (C) High-resolution image showing the wedge-shaped area of delamination through cartilage just above the tidemark. (D) Vascularized neo-tissue partially covering the completely delaminated plug. SDOCA, sterilized and decellularized osteochondral allograft.

- The bone was similar in both samples, with some areas with viable cells and some completely devoid of cells (Figure 9B).
- The partially delaminated plug showed chondrocyte-like cells near the tidemark of the cartilage and where the cartilage was starting to delaminate (Figure 9C).
- The delaminated plug had no viable cells in the cartilage, but there was a very cellular neo-tissue on the bone surface. This tissue was very fibrous, with some sections resembling cartilage and some areas very vascularized (Figure 9D).

DISCUSSION

To our knowledge, this is the largest cohort of the SDOCA implant reporting clinical and radiological outcomes. Unexpectedly, 23 of 32 knees (72%) were considered treatment failures, with a 2-year survivorship rate of only 19.6%. Age was significantly predictive of failure, with a hazard ratio of 1.68 per 1 SD older. Several definitions for cartilage failure have been proposed in the literature. In the context of this investigation, we considered failure when patients were diagnosed by MRI and/or arthroscopy with structural failure of the implant. Cases where arthroscopy was required for simple debridement or lysis of adhesions were not considered failures. These failure criteria mirror those reported in the literature in several multicenter cohorts. Recently, the SDOCA implant has become available in the United States for the treatment of cartilage lesions, predominantly in the knee. The published indications for this implant overlap those of other procedures, such as OAT, autologous chondrocyte implantation (ACI), and fresh osteochondral allograft (OCA) transplantation. In the presented cohort, the majority of patients had previously undergone and failed other forms of cartilage repair, such as microfracture, OAT, OCA, or ACI. After presenting our preliminary data, concerns were raised that due to having previously failed these procedures, patients should not have undergone SDOCA implantation—a potential explanation of the high failure rate. However, the prospective study protocol sponsored by the manufacturer specifically allowed inclusion of patients with failed prior cartilage repair. Furthermore, most patients treated with advanced cartilage repair procedures, such as OCA or ACI, present after having failed less invasive options such as microfracture or OAT. A history of prior failed cartilage repair is therefore the rule, rather than the exception, in our patient population. To further address this concern, we reviewed patients treated at our centers with other advanced cartilage repair procedures during the same time period in which we used the SDOCA implant (between first and last patient treated with SDOCA). Patients were treated with similar indications, but generally even larger lesion sizes than those that underwent SDOCA implantation. Patients were evaluated by the same failure criteria as those for the SDOCA implant. One center treated 60 patients with ACI with a 13% failure rate, and 33 patients with OCA with an 18% failure rate. The other center performed 47 ACIs and 22 OCAs with 19% and 18% failure rates, respectively. This stands in stark contrast with the 72% failure rate of the SDOCA implant reported in this investigation.

The experimental equine study that supported SDOCA for clinical use compared fresh equine osteochondral graft and decellularized equine graft against no treatment (control) at 3-, 6-, 9-, 12-, and 18-month intervals. Histological specimens at 18-month follow-up demonstrated smooth cartilage surface, intact extracellular matrix, new bone tissue formation, complete bony integration, and no bone cysts. The articular cartilage in the decellularized graft remained devoid of viable chondrocytes, but the tissue did not appear to degenerate at 18 months after implantation. In addition, little or no cartilage degeneration was noted on the opposing cartilage surface. One potential explanation for the difference between animal and human experience could be the addition of gamma irradiation for terminal sterilization of grafts intended for human use.
while the grafts used in the equine study were sterilized with ethylene oxide.

The only clinical study in the literature of the SDOCA implant in a human was a case report of a 16-year-old patient with medial femoral condyle osteochondritis dissecans (1.6 × 1.5 cm) with concomitant tears of the anterior cruciate ligament (ACL) and meniscus.13 The patient was treated with a 15-mm SDOCA plug with 25 months of follow-up. The implant showed complete bone incorporation and restoration of native condylar curvature during a second-look arthroscopy due to ACL rupture and medial meniscal tear.

With regard to imaging, clinical and radiological outcomes correlated poorly, a common finding with cartilage procedures. The most common MRI findings were an irregular and disrupted subchondral bone plate (all grafts for both observers), signal alterations of the subchondral bone (21 grafts for observer 1; all grafts for observer 2), and inhomogeneous articular surface (all grafts for both observers), bone (21 grafts for observer 1; all grafts for observer 2), and synovial thickening (all grafts for both observers). The presence of a joint effusion was associated with worse clinical scores. This corroborates findings from previous authors showing that effusions are associated with pain in knee osteoarthritis.11 Unfortunately, no strong evidence is available demonstrating that MRI is reliable in predicting clinical outcome of cartilage repair.1,2

As with most studies of surgical interventions, we acknowledge several limitations. This is a prospective case series without a control group and includes a small sample size and heterogeneous characteristics such as age, lesion size, and number of grafts used. In addition, as expected with the low distribution of MOCART scores and with relatively few numbers of patients, limited statistically significant correlations were found. However, the multicenter nature of this study provides increased external validity of the evidence, and our patient demographics mirror those seen in clinical practice for cartilage repair.

In summary, to our knowledge this is the largest study to report clinical and radiological outcomes of the SDOCA implant for the treatment of cartilage lesions in the knee. The implant demonstrated a high failure and reoperation rate with short-term follow-up and should be used judiciously—possibly in situations where a short-term bridging option is acceptable.

ACKNOWLEDGMENT

The authors acknowledge Carolina P.B. Gracitelli for statistical analysis.

REFERENCES