HIP TECHNOLOGIES

Cartilage restoration of the hip using fresh osteochondral allograft

RESURFACING THE POTHOLES

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Cartilage defects of the hip cause significant pain and may lead to arthritic changes that necessitate hip replacement. We propose the use of fresh osteochondral allografts as an option for the treatment of such defects in young patients. Here we present the results of fresh osteochondral allografts for cartilage defects in 17 patients in a prospective study. The underlying diagnoses for the cartilage defects were osteochondritis dissecans in eight and avascular necrosis in six. Two had Legg-Calvé-Perthes and one a femoral head fracture. Preoperatively, an MRI was used to determine the size of the cartilage defect and the femoral head diameter. All patients underwent surgical hip dislocation with a trochanteric slide ostotomie for placement of the allograft. The mean age at surgery was 25.9 years (17 to 44) and mean follow-up was 41.6 months (3 to 74). The mean Harris hip score was significantly better after surgery (p < 0.01) and 13 patients had fair to good outcomes. One patient required a repeat allograft, one patient underwent hip replacement and two patients are awaiting hip replacement. Fresh osteochondral allograft is a reasonable treatment option for hip cartilage defects in young patients.

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Insult to the articular cartilage of the hip is a source of pain, reduced function and can be a cause or consequence of degenerative joint disease.1 Currently, there is no established technique for treating these cartilage defects. Treatment options have generally been adapted from the management of similar lesions at the knee2-4 and include osteotomy, microfracture and autologous chondrocyte implantation (ACI).5-11 However, managing these injuries can be technically challenging and each of the techniques have their limitations and successful outcomes are not guaranteed.

Fresh femoral osteochondral allografts have been used for decades, although they are certainly not commonplace.12 The advantage of this technique is that it can restore true type II hyaline cartilage and at least in part correct abnormal bony morphology. Meyers13 first published a series of 21 patients and, based on his clinical results, recommends that femoral osteochondral allografts are indicated in patients who are less than 50, have no evidence of osteoarthritis (OA), and have defects larger than 2.5cm². Meyers suggested that allografts should not be used in patients with steroid induced avascular necrosis where there is a failure rate of 50%. Other contraindications to using this procedure include inflammatory arthropathy and lesions that are uncontained and involve greater than 50% of the femoral head. Evans and Providence14 described a 12 mm thick fresh osteochondral graft via surgical hip dislocation (SHD) in a single patient for a case of osteochondritis dissecans (OCD) in the weight-bearing zone of the femoral head; their one-year follow-up results had a favourable outcome.

Here we present the clinical and radiological outcomes of the treatment of hip cartilage defects by means of fresh-stored osteochondral allografts via a SHD with a femoral trochanteric ostotomie in young, symptomatic patients.

Patients and Methods

For this prospective study, carried out between 2008 and 2013, institutional review board approval was obtained to analyse all fresh femoral and acetabular osteochondral allograft cases. Each eligible patient gave consent and had pre-operative routine radiographs including an anteroposterior and lateral of the involved hip (Fig. 1a). In addition, all 17 patients had a pre-operative MRI in which the size of the cartilage defect and the femoral head diameter were determined (Fig. 1b). All MRI examinations were performed using a 3T magnet (Skyra, Siemens AG, Erlangen, Germany) with an 18-channel flex torso array coil.
Axial, coronal and sagittal images were constructed using T1-weighted fast spin echo (FSE) and intermediate-weighted fat-saturated FSE sequences. In addition, intermediate-weighted FSE radial acquisitions perpendicular to the acetabulum with slices intersecting through the center of the hip joint were obtained. After the pre-operative evaluation, the patients were placed on a waiting list until a suitable donor became available. Donors were identified through the Multiple Organ Retrieval and Exchange (MORE) program of Ontario, Canada, as being eligible for tissue donation according to the criteria set by the American Association of Tissue Banks. Blood for serology and cultures was collected (no tissue typing or matching is required for osteochondral transplantation). During the harvesting process the donor’s femoral head was measured by a caliper and matched to a respective recipient within a 1 mm difference in head diameter. The fresh osteochondral femoral head allograft was then placed in a sterile container with 1 g cefazolin and 50,000 units of bacitracin per liter of Ringer’s lactate solution (B. Braun Medical Inc., Vaughan, Ontario, Canada). The container was stored at 4°C until transplantation. Although fresh osteochondral material remains viable for transplantation for up to four weeks we preferred to perform the transplantation within two weeks of harvesting, after all culture and serology tests determined that it was clear of infection.

All surgeries were performed via a SHD with a modified trochanteric osteotomy in the lateral decubitus position. The femoral head was dislocated and the osteochondral lesion was identified. The lesion was defined by first removing the centre of the damaged cartilage followed by removal of the peripheral, damaged cartilage until healthy edges were obtained. A commercially available system (Arthrex, Naples, Florida) was used to prepare the host bone and donor graft for implantation. The host defect was prepared to receive the allograft by creating a cylindrical defect using a power reamer over a guide wire. The reamer was advanced until there was bleeding bone within the bed of the graft site. The matching area was harvested from the donor using a hollow trephine reamer. The plug height was shaped according to the depth of the host bed dimensions. The osteochondral plug was then placed gently into the defect and tamped into position until the articular surface was flush with the host articular cartilage (Fig. 2). The hip was reduced and the joint capsule was closed. The greater trochanter was reattached with three small fragment (3.5 mm) or two large fragment (4.5 mm) cortical screws. After surgery, the patient was allowed to perform toe touch weight-bearing for 12 weeks. Advancement to full weight bearing was carried out after healing of the greater trochanter was confirmed radiologically (Fig 3a).

Follow-up consisted of clinical and radiological examination pre-operatively, and post-operatively at six weeks, six months, one year and then annually. Clinical evaluations included the determination of Harris hip scores (HHS) that were recorded pre-operatively and at the time of most recent follow-up. Post-operative MRI was performed at six months or longer post-operatively in order to assess the allograft (Fig. 3b). However, while all patients returned for their regularly scheduled clinical follow-up, some patients from outside our region, chose not to have follow-up MRI as cost of travel was prohibitive.

For those patients with post-operative MRI, the Osteochondral Allograft MRI Scoring System (OCAMRISS) was used to assess the allograft using coronal T1-weighted FSE images. The OCAMRISS is a comprehensive MRI score that incorporates analysis of five cartilage features including cartilage signal, fill, cartilage edge integration with host, and calcified cartilage integrity, four bone...
features including subchondral bone plate congruity, subchondral bone marrow signal, osseous integration at the host-graft junction, and presence of cystic changes at the host-graft junction, and four ancillary features. We did not include the ancillary features for the OCAMRISS on our patients, as these features are most relevant for knee osteochondral allografts. Therefore, the best OCAMRISS score for our study would be 0 and the worst would be 13. MRIs were scored according to the OCAMRISS criteria by two independent authors (DMT, VK).

**Statistical Analysis.** A paired sample T-test was used to compare mean pre-operative and mean post-operative HHS. An intra-class correlation coefficient (ICC) was calculated to assess agreement between MRI reviewers for the OCAMRISS score. Spearman’s correlation was used to determine if there was significant correlation between OCAMRISS score and post-operative HHS. All statistical analysis was performed using SPSS Version 22 (IBM Corp., Armonk, New York).

**Results**

We included 17 patients (Table I) in the study, consisting of nine males and eight females. The mean age at surgery was 25.9 years (17 to 44). The underlying aetiology of the cartilage defect was OCD in eight hips (seven femoral lesions and one acetabular lesion), avascular necrosis (AVN) in six hips (three due to steroid use, two due to hip dislocation and one idiopathic), Legg-Calve-Perthes disease in two hips, and femoral head fracture without dislocation in one hip.

The mean time from surgery to last follow-up was 41.6 months (3 to 74). The average HHS improved significantly (p < 0.01) from 52.6 (41 to 67) to 72.9 (47 to 85). Based on most recent HHS, seven patients (41.2%) had good results (HHS between 80 and 89), six patients (35.3%) had fair results (HHS between 70 and 79), and four patients (23.5%) had poor results (HHS less than 70). Radiological review at six weeks confirmed that all trochanteric osteotomies had healed and all patients were fully weight-bearing.

Final HHS scores indicated that 13 of 17 patients (76%) had fair to good outcomes, this included one patient who went on to early graft failure, possibly related to failure to comply with non-weight-bearing restrictions immediately post-surgery. His graft went on to collapse, but showed no progression of arthritis, as such he underwent a repeat allograft nine months after the initial allograft and at latest follow-up his HHS score was 84.

Of the 17 patients, four had poor outcomes. One patient whose AVN was linked to long-term steroid use for treatment of leukemia had progression of her arthritis with increased pain. She was subsequently converted to a hip replacement six months after her femoral allograft transplant procedure. One patient had persistent lateral thigh pain, which resolved upon removal of trochanteric screws at one year. Two of the four patients that had poor outcomes showed ongoing progression of pain and arthritis at their latest follow-up. Both of these patients were diagnosed pre-operatively as having their femoral head defects secondary to Legg-Calve-Perthes disease and now await a total hip replacement (THR). The remaining patient with a poor outcome had ongoing progression of her pain, however, there was no radiographic progression of her arthritis.

An MRI was carried out in ten patients at a mean of 22 months (6 to 62) after their osteochondral allograft. The ICC was 0.91 indicating excellent agreement between the two reviewers for the OCAMRISS score. The mean OCAMRISS score for the patient cohort was 7 (0.5 to 11). There was no significant correlation between OCAMRISS score and post-operative HHS (Spearman correlation = -0.09, p = 0.80).
Discussion

Cartilage defects of the femoral head and acetabulum secondary to OCD, AVN or trauma can result in significant pain and dysfunction of the hip. Left untreated, the natural history of these defects, typically found in the weight-bearing dome of the hip, is to progress to early development of degenerative changes.1,20 While a THR would be a reliable option to relieve pain and restore function, these cartilage defects are commonly seen in young, active patients and as such, there are concerns over implant longevity and survivorship.21-23

Microfracture4,24 is the most widely reported technique in the literature for management of chondral injuries of the hip,6-8 likely due to the relative ease of the procedure as well as surgeon familiarity with the technique. However, this technique is limited by its inability to produce native articular hyaline cartilage and the type I collagen that subsequently forms has inferior biological and mechanical properties that make it more prone to degeneration.25 Based on studies of the knee and ankle, success of microfracture is typically limited to management of lesions that are focal and smaller than 2 cm².26,27

Few reports have been published on ACI for femoral head lesions. Fontana et al28 compared femoral head lesions greater than 2 cm² treated with debridement or matrix assisted ACI (MACI), a technique that uses a biodegradable scaffold for chondrocyte delivery. Fontana’s results showed a favourable clinical outcome with MACI compared with debridement alone. Conventional ACI for femoral head defects must be performed via a SHD, while MACI can be performed arthroscopically. Both procedures are technically challenging due to the difficulty of accessing the hip and neither address underlying morphological abnormalities.

Fresh osteochondral allografts are a possible alternative for young patients with large cartilage defects. The advantages of fresh osteochondral grafts include the ability to perform them in a single stage procedure and to treat large defects. At a histological level, the use of allograft provides the patient with hyaline cartilage as opposed to fibrocartilage. Also, future THR is not compromised, unlike proximal femoral osteotomy that may make the future hip replacement technically challenging.21

Limitations of osteochondral allograft include the necessary post-operative weight-bearing restrictions on patients for six to 12 weeks. Obtaining matched donors is a difficult and expensive process. Finally, as with other cartilage repair techniques, fresh osteochondral grafts require a surgical hip dislocation, which is an invasive procedure compared with hip arthroscopy and places the patient at risk of trochanteric nonunion and irritation from subsequently redundant metal ware.

Of our 17 patients, 13 (76%) had fair to good clinical outcome scores and there was a significant (p < 0.01) improvement in the average HHS. We have previously reported on the results of eight of the patients included in

Table I. Patient demographics and characteristics of femoral head defects with outcomes

<table>
<thead>
<tr>
<th>Patient</th>
<th>Gender</th>
<th>Side</th>
<th>Pre-op Diagnosis</th>
<th>Age at Surgery</th>
<th>Follow-up (mths)</th>
<th>Pre-op HHS</th>
<th>Post-op HHS</th>
<th>Outcome*</th>
<th>OCAMRISS Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>Left</td>
<td>OCD</td>
<td>33</td>
<td>50</td>
<td>61</td>
<td>80</td>
<td>Good</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>Right</td>
<td>OCD</td>
<td>18</td>
<td>69</td>
<td>57</td>
<td>84</td>
<td>Good</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>Right</td>
<td>OCD</td>
<td>42</td>
<td>69</td>
<td>50</td>
<td>53</td>
<td>Poor (ongoing pain without progression of OA)</td>
<td>N/A</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>Left</td>
<td>AVN Idiopathic</td>
<td>25</td>
<td>73</td>
<td>57</td>
<td>74</td>
<td>Good</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>Right</td>
<td>AVN Dislocation</td>
<td>18</td>
<td>50</td>
<td>53</td>
<td>84</td>
<td>Good (allograft revised)</td>
<td>N/A</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>Right</td>
<td>AVN Steroids</td>
<td>18</td>
<td>74</td>
<td>N/A</td>
<td>N/A</td>
<td>Poor (converted to THA)</td>
<td>N/A</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>Left</td>
<td>Femoral Head Fracture</td>
<td>22</td>
<td>74</td>
<td>61</td>
<td>88</td>
<td>Good</td>
<td>9</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>Left</td>
<td>OCD</td>
<td>17</td>
<td>36</td>
<td>65</td>
<td>85</td>
<td>Good</td>
<td>N/A</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>Right</td>
<td>OCD Acetabulum</td>
<td>38</td>
<td>36</td>
<td>43</td>
<td>79</td>
<td>Fair</td>
<td>0.5</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>Right</td>
<td>Perthes</td>
<td>20</td>
<td>24</td>
<td>42</td>
<td>47</td>
<td>Poor (progression of OA, awaiting THR)</td>
<td>9</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>Right</td>
<td>OCD</td>
<td>19</td>
<td>24</td>
<td>56</td>
<td>82</td>
<td>Good</td>
<td>9.5</td>
</tr>
<tr>
<td>12</td>
<td>F</td>
<td>Right</td>
<td>OCD</td>
<td>34</td>
<td>24</td>
<td>43</td>
<td>80</td>
<td>Good</td>
<td>4</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>Left</td>
<td>AVN Dislocation</td>
<td>29</td>
<td>24</td>
<td>41</td>
<td>77</td>
<td>Fair</td>
<td>N/A</td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>Left</td>
<td>AVN Steroids</td>
<td>32</td>
<td>24</td>
<td>46</td>
<td>72</td>
<td>Fair</td>
<td>3.5</td>
</tr>
<tr>
<td>15</td>
<td>F</td>
<td>Right</td>
<td>Perthes</td>
<td>17</td>
<td>13</td>
<td>67</td>
<td>58</td>
<td>Poor (progression of OA, awaiting THR)</td>
<td>9.5</td>
</tr>
<tr>
<td>16</td>
<td>F</td>
<td>Right</td>
<td>OCD</td>
<td>20</td>
<td>13</td>
<td>48</td>
<td>75</td>
<td>Fair</td>
<td>11</td>
</tr>
<tr>
<td>17</td>
<td>M</td>
<td>Right</td>
<td>AVN Steroids</td>
<td>44</td>
<td>3</td>
<td>N/A</td>
<td>70</td>
<td>Fair</td>
<td>N/A</td>
</tr>
<tr>
<td>Total</td>
<td>52.9%</td>
<td>Male</td>
<td>Right</td>
<td>Mean 25.9 Mean 41.6 years</td>
<td>Mean 52.6</td>
<td>Mean 72.9</td>
<td>41.2% Good; 35.3% Fair; 23.5% Poor</td>
<td>Mean 7 (0.5 to 11)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>64.7%</td>
<td>Right</td>
<td>47% OCD, 35.3% AVN, 11.8% Perthes, 5.9% Fracture</td>
<td>Mean 41 to 67</td>
<td>Mean 47 to 85</td>
<td>41.2% Good; 35.3% Fair; 23.5% Poor</td>
<td>Mean 7 (0.5 to 11)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

AVN, avascular necrosis; OCD, osteochondritis dissecans; OA, osteoarthritis; THR: total hip replacement; N/A, not available; OCAMRISS, osteochondral allograft MRI scoring system

* Outcome based on Harris hip score (< 70 poor; 70 to 79 Fair; 80 to 89 Good; 90 to 100 Excellent)
the present study.29 We concluded in this earlier study, that the patient with intractable post-allograft pain and progressive degenerative changes, who ultimately went on to conversion to THR six months after allograft, was a poor candidate for osteochondral allograft because of her long-term steroid use. We suggested at the time that steroid-induced AVN may predispose a patient to failure with an osteochondral allograft as the host bone may not be amenable to graft osteointegration due to diffuse metabolic damage, subchondral bone sclerosis and compromised vasculature.30-34 Our early findings concur with Meyers13 findings of high failure rates for allograft in steroid-induced AVN cases. However, in our present data, two patients with steroid-induced AVN had fresh osteochondral allografts and at latest follow-up, both are doing well clinically and radiologically. These two patients were on short-term steroids for an acute illness and had ceased their steroid use at least one year prior to undergoing the allograft procedure. The failed case, on the other hand, was a patient who required high dose steroid treatment for leukemia both before and after her allograft.

Two of the remaining failures in the study were female patients initially diagnosed as having Legg-Calve-Perthes disease of their hips. Both patients had considerable pre-operative joint deformity (Fig. 4a). Intra-operatively both patients were found to have global cartilage damage with evidence of early arthritic changes (Fig. 4b). Possible explanations for poor outcome of the fresh osteochondral allograft in this patient cohort are extensive residual deformity leading to excessive stresses on the graft or irreversible osteoarthritic changes present at time of surgery. As such, the progression of arthritis may be an inevitable consequence. The natural history of non-operatively managed Perthes is development of moderate to severe osteoarthritis in 44% of patients within a 20 year period from diagnosis.35 By the sixth or seventh decade of life, regardless of surgical intervention, the majority of Perthes patients will display some moderate degree of joint degeneration.36 Perhaps correction of the bony deformities at the time of allograft implantation may yield a more hospitable environment for the osteochondral allograft to be successful.

In general, the MRI appearance of the graft did not correlate with post-operative HHS or a poor outcome in our study, as we did not find a significant correlation with the OCAMRISS score. Post-operative MRI scans were only obtained in ten patients and therefore we cannot make a definitive conclusion regarding the utility of MRI for assessment of the hip osteochondral allografts.

In conclusion, the follow-up results on our patients with hip cartilage defects treated with a fresh osteochondral allograft, are promising and show similar success rates to the use of osteochondral allograft for cartilage defects in other joints of the body.37-39 Based on our findings the ideal candidate for a fresh osteochondral allograft to treat a cartilaginous defect of the hip would be a young, compliant patient with minimal pre-existing degenerative changes or deformity, and a cartilage defect that is not related to long-term steroid use.

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