Osteochondral transfer: autograft, allograft and scaffolds
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Osteochondral Transfer
Indications: deficiency of subchondral bone and cartilage: OCD, AVN, tumor

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<thead>
<tr>
<th>Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>OC autograft</td>
<td>• Good incorporation</td>
<td>• Donor site morbidity</td>
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<td>(OATS, mosaicplasty)</td>
<td>• Autologous tissue with no risk of disease transmission</td>
<td>• Generally rec. for lesions ≤ 2cm²</td>
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<td>• Hyaline cartilage</td>
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<tr>
<td>OC allograft</td>
<td>• No donor site morbidity</td>
<td>• Risk of disease transmission</td>
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<td>• Able to accommodate large lesions (&gt; 2cm²)</td>
<td>• Delayed biologic incorporation</td>
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<td>Scaffolds</td>
<td>• No donor site morbidity</td>
<td>• Availability limited</td>
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<tr>
<td></td>
<td>• No risk of disease transmission</td>
<td>• Labs are variable for chondrocyte viability</td>
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<td>• Fills with fibrocartilage or “hyaline-like” cartilage</td>
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MRI as Primary Outcome Measure: Cartilage Repair
♦ Signal intensity of tissue (ROI)
♦ Integrity/hypertrophy of periosteal flap
♦ Morphology; presence/absence of displacement (ACI/ OCA)
♦ Interface with native cartilage
♦ Volume of repair “fill”
♦ Appearance/morphology of subchondral bone
♦ Assess adjacent/opposite articular cartilage
♦ Presence/absence of inflammatory synovitis

♦ MR observation of cartilage repair tissue (MOCART) Marlovits et al; Eur J Radiol 2006; 57:16-23
  – Correlated to KOOS and VAS; significant correlation for fill, structure, subchondral bone, SI
  – ICC (3 readers); κ range: 0.765-1.00

Quantitative MR Imaging of Cartilage Repair in a Goat Model (ORS 2009)
21 goats: 16 defects – treated with press-fit proprietary allograft (MFC); 5 controls necropsy at 6 months

- Studied the prevalence of edema like signal intensity on MRI in patients who underwent osteochondral autograft transplantation (OCT) in the knee.
  - Patients were followed by MRI at 1, 3, 12, and 24 months post-operatively.

**Results**
- Prevalence of edema-like signal intensity:
  - 70% of patients after 1 month
  - 60% of patients after 24 months
- No significant correlation between:
  - Presence of edema and clinical pain score
  - Presence of edema and morphologic MRI findings

The presence of edema-like signal intensity is often seen in patients who underwent OCT but it does not significantly relate to MRI morphologic findings or knee pain.

**Comparison of fresh osteochondral autografts and allografts: a canine model**

- 18 adult dogs with bilateral OCA (allograft and autograft); assessed at 3 and 6 months
- No difference in bony incorporation between auto and allografts
- Fissures at peripheral integration in 90% of cases although subchondral bone was well incorporated
- T2 values showed no significant difference, correlating to lack of difference in articular cartilage composition on histology
- No difference in biomechanical testing

**Fresh osteochondral allograft (Gross, Garrett) +/- osteotomy**
- May have concomitant osteotomy, meniscus (with tibia) and SS hardware
- Dowel grafts: Technically easier, press-fit
  - Femoral or central patella lesions

**Shell osteochondral allograft**
- Not limited by size, shape or location
- Tibial plateau and posterior femoral lesions

**OCA GRAFT PROPERTIES AND STORAGE**
- Fresh (preferred): cells viable, bone immunologic
- Frozen: cartilage dead, bone incorporation
  - Fate of Bone in Osteochondral Allografts
    - Bone ingrowth determined by degree of tissue matching
    - Cortical and cancellous bone affected (Stevenson, 1991)
    - Fracture, nonunion, subchondral collapse, resorption
  - Fate of Cartilage in Osteochondral Allografts
    - Mismatched grafts
      - Cartilage degeneration
      - Inferior biochemically
      - Plasma cells, lymphocytes in synovium (Stevenson, 1991)
    - Freezing → chondrocyte apoptosis

- *In vitro* studies* have demonstrated compromise in fresh grafts with increased storage time
- After 14 days:
  - decrease in chondrocyte viability
  - degradation of biomechanical properties

*BALL CORR 2004, WILLIAMS AJSM 2004*

- Williams et al. studied the material properties of hypothermically stored (nutritive medium at 4°C) allograft specimens used to repair osteochondral defects.
- 12 sheep knee condyles were stored for 1, 8, 15, 29, 45, or 60 days.
- After storage, the matrix proteoglycan and water content were determined, as was chondrocyte density and viability.
- Material properties of knee condylar specimens stored in hypothermic medium decreased over a 60 day interval.
  - Mean cartilage viability:
    - 100% (day 0)
    - 80.2% (day 15)
    - 51.6% (day 60)
  - Mean proteoglycan content in the matrix decreased from day 8 to day 60.
- Study showed that the material properties of hypothermically stored condylar specimens decrease over time, which is consistent with compromised cellular and structural properties of the cartilage.

**Imaging of Osteochondral Allografts**
- Immune reaction does occur: surface antigens present
- More cells: greater response
- Not for pts. with collagen vascular disease or inflammatory joint processes
- Sirlin et al. correlated MRI of shell osteochondral allografts to the results of antihuman leukocyte antigen antibody screening (*Radiology* 2001; 219:35-43)
  - Pts. who expressed positive humoral immune responses were associated with decreased incorporation, greater marrow edema pattern and a higher proportion of surface collapse of their graft.
  - Probability of viremia at time of donation HIV 1:55,000; HBV 1:34,000
    (w/ nucleic acid amplification HIV 1:173,000; HBV 1:100,000)

**Imaging of Osteochondral Allografts**
- Prospective, longitudinal study of cartilage defects treated with hypothermically stored fresh osteochondral allografts
- Ideal appearance:
  - nondisplaced, flush, incorporated
  - graft signal: consistent w/ fat
  - isointense cartilage signal to native hyaline
  - smooth peripheral integration
- Allografts remain intact without displacement
  - 10/18 (56%) grafts were flush
  - 3/18 (17%) had complete trabecular incorporation
    - (11 partial; 4 poor)
  - fissures noted at the graft/host interspace in 78%
  - poor incorporation was noted in 22% grafts: persistent bone marrow edema pattern and/or subchondral marrow fibrosis
  - collapse of the subchondral bone in the graft was correlated to lack of bony integration based on signal characteristics


**OCA Placement and Incorporation Issues:**

**Articular Surface vs. Subchondral Bone**
- Koh et al (AJSM 2006; 34: 116-119): in vitro biomechanical study of OC grafts showed that slightly sunk grafts were still able to reduced elevated contact pressures to normal levels but elevated or angled grafts increased contract pressures (better to have slightly sunk versus proud grafts)
Reduction of Susceptibility: Current Capabilities

- Frequency shift misregistration causes signal hyperintensity and void
- Distortion in slice and readout $\propto \frac{1}{\text{strength of } G_z \text{ and } G_x}$
  - $\uparrow G_x$ strength, $\downarrow$ misregistration
  - Wide receiver bandwidth (up to 500Hz/pixel)
    - Issues of gradient performance and linearity; performance off of isocenter
  - Thinner slices
- High resolution frequency direction: $\downarrow$ voxel size, $\uparrow$ spatial resolution and definition of metal-induced distortion

Reducing susceptibility artifact

- Use lower field strength (B0) magnets (1.5T preferred)
- Use a broad receiver bandwidth
  - Inverse relationship between RBW and degree of linear misregistration artifact
  - GE 100-125kHz over frequency range; Philips/Siemens 350-500Hz/pixel
  - BONUS: will reduce IES, allowing for longer ETL and reduced scan time, thus permitting more excitations: INCREASE SNR
- Frequency selective fat suppression
  - Relies of difference in precessional frequencies between fat and water
  - In presence of metal, ability to perceive fat and water at different frequencies is hampered, resulting in inadvertent suppression of water
  - Use fast STIR or more robust fat/water separation techniques (IDEAL)
- Gradient echo sequences
  - No refocusing pulse
  - Increased dephasing (T2*) and large areas of signal void

Bedi et al. Maturation of Synthetic Scaffolds for Osteochondral Donor Sites of the Knee: An MRI and T2-Mapping Analysis. Cartilage, vol.1 no.1, 2010

- 26 patients OATS for defects in the knee (n=21) or talus (n=5)
  - Mean plug size: 9 mm (range: 6 mm – 11mm)
- 78% of plugs demonstrated near complete to complete fill at early follow-up ($\leq$6months) - 90% demonstrated near complete to complete fill at $\geq$16month
- T2 values approached that of normal cartilage with increasing duration after surgery (p<0.004)
- Plug appearance on MRI improves significantly with greater postoperative duration, with T2 relaxation times approaching native hyaline cartilage but less organized stratification
- Worse appearance when placed adjacent to an autologous plug or with more than 2 adjacent synthetic plugs

Osteochondral Transfer

Each has advantages and disadvantages but all do poorly in the face of bipolar disease or frank osteoarthritis MRI, particularly with quantitative techniques, is the most effective means by which to noninvasively assess biologic incorporation and maturation of the grafts, as well as the reaction of the host compartment.

References