Imaging of Cartilage Repair

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Cartilage Repair Options

• Direct repair
• Marrow stimulation
• Autologous transplantation
• Allogeneic transplantation
• Cell transplantation
• Acellular Scaffolds
• Combination techniques

Direct Fixation of OCD

Large osteochondral defect
Displaced fragment

Repaired by direct fixation

Marrow Stimulation

Débridement
Drilling
Microfracture

Abrasin Arthroplasty

Autologous Osteochondral Transplantation

Donor Site
Recipient Site

Osteochondral Allograft

Osteochondral “Shell” Allograft
Autologous Cell Transplantation
Autologous Chondrocyte Implantation

Stage 1
Stage 2

Courtesy Tom Minas, MD Cartilage Repair Center, BWH, Boston MA

Acellular Scaffold - 2 plugs in MFC

Intra-operative
7 Months

Surface fills from periphery

Photo courtesy of Tom Minas, MD, BWH Cartilage Repair Center

Direct Fixation of OCD by AOT

• Osteochondral lesion fixed in place by osteochondral plugs
• No cartilage defects from pins or screws
• No screw removal needed

Courtesy Anthony Miniaci, MD, Cleveland Clinic Sports Health Center

Direct Fixation of OCD by AOT

Preoperative

1 Month Postop
3.5 Months Postop

**Cartilage Repair: Treatment Choice Decision**

- Lesion size and depth
  - <4cm$^2$: marrow stimulation, AOT
  - 2cm$^2$ – 12cm$^2$: ACI, Allograft
- Only symptomatic lesions treated
- Patient activity level
- Patient expectations

**Postoperative Assessment**

- Defect fill
  - volume & thickness
  - surface contour
- Integration of repair tissue
  - repair-bone interfaces
  - repair-native cartilage
- Subchondral bone response
  - “edema-like” marrow signal
  - cyst formation
- Non-repair site complications
  - adhesions
  - new defects

**Defect Fill**

- Complete fill expected early
  - Autologous osteochondral transfer (OATS, mosaicplasty, etc.)
  - Osteochondral allograft
  - Most “classic” ACI & CACI (collagen-assisted ACI)
  - Direct osteochondral repair
- Initial underfilling expected
  - Microfracture
  - Cell-seeded scaffold ACI (MACI, Hyalograft-C, etc.)

**Complete Fill Restores Articular Surface**

**33 y.o. male ACI’s of MFC, Trochlea, & Patella**

*Intraoperative 14 months 2nd look scope*

*Photos courtesy of Tom Minas, MD  BWH Cartilage Repair Center*
Postoperative MR of MFC 4 yrs Postop

Complete Fill

ACI: Maturation

3 weeks
Initial "overfill"

11 months
Surface restored

19 months
Surface maintained

Microfracture – Tissue Growth

2 months Postop

SPGR fat sat
Initial underfilling

7 months Postop

SPGR fat sat
Contour restored

Cell-seeded Scaffold ACI

Progression of defect fill

3 Months

12 Months

Autologous Osteochondral Transplantation

PDW FSE

"Normal" AOT Lateral Trochlear Donor Site

- Normal marrow fills donor site
- Typically mild underfilling

11 Months

Courtesy of Michael Recht, MD

Abnormal Defect Fill

Drilling: Failure of Tissue Growth
- No defect fill
- Continued symptoms 6 months following drilling
- Cysts formed along drill tracks

Pre-operative: Lesions LFC, LTP

Failed Microfracture
Poor fill, cyst formation

Failed Microfracture
Poor fill, cyst formation

Scope courtesy Tom Minas, MD Cartilage Repair Center, BWH, Boston MA

ACI: Failure of Tissue Growth
44 y.o. woman with catching symptoms 3 months after 25 x 16mm ACI to MFC for an osteochondral defect
3 mos. postop

Scope courtesy Tom Minas, MD, BWH Cartilage Repair Center
Subsidence of Plugs – 3 months Post-op

Restored Contour - 35 months Post-op

Degeneration of Repair Tissue
3 yrs. After Abrasion

ACI: Periosteal Hypertrophy
Painful catching 7 mos. after revision ACI:

Referred for Painful Knee Donor Site
AOT – Knee to Talus

Repair-Bone Integration

Irregular contour, advancement of subchondral bone plate at base of lesion

9 months Post-op: hypertrophic tissue
Not seen by MR, but marrow edema present

Complete Integration

ACI

13 Months

Autologous Osteochondral Transplantation

Lesion & Donor Bone

Completed Graft

Osteochondral Allograft

Edema-like signal in graft

Osteochondral Allograft

3 months Postop

Edema-like signal at graft interface

Osteochondral Allograft

6 months Postop

MFC graft interface normal

OCA – MFC & MTP

12 months Postop

Mile edema-like signal MTP graft interface

Courtesy of Michael Recht, MD

Courtesy of Robert D. Boutin, MD

Courtesy of William Bugbee, MD & Robert D. Boutin, MD

**Failed Repair-Bone Integration**

**Osteochondral Allograft: Articular Incongruity**
12 months Postop

**Failed AOT – Osteonecrosis of Plugs**
7 months Postop

**Repair-Cartilage Integration**

**Loose Plugs Toggle When Probed**

Scope courtesy of Tom Minas, MD, BWH Cartilage Repair Center

PDW FSE
PDW FSE fat sat

ACI: Displaced Delamination
Graft Integration

- Cartilage Margins:
  - dark
  - indiscernible
  - fluid-like
- No fluid between graft & bone

Normal Maturation of ACI-Cartilage Interface

Microfracture

Immature interface or fissure?

Failed Repair-Cartilage Integration

ACI: Failure of ACI-cartilage Integration

- Edema-like signal “focused” on leading edge of ACI
- Small delamination at leading edge
- Posterior part of ACI intact

Subchondral Bone Response
Resolution of edema-like marrow signal
Normal ACI
2.5 Weeks  4.3 years

Microfracture – Maturation
3 weeks
6 months
12 months

Abnormal Subchondral Bone Response

ACI Failure With Generalized Edema
- 1.3 years after 8.4 cm² revision ACI to MFC
- Soft fibrous repair, hypertrophy and large cysts

AOT: Postoperative Cyst Formation
- Painful ankle 13 months after 2 plugs knee to ankle
- Bony portion well-incorporated

AOT with cyst formation
- Cysts form at margins of plugs

Osteochondral Transfer: Knee to Talus

Failure of Cartilage-cartilage Integration?

Osteochondral Plug

“Residential” Cartilage

Cleft between transferred cartilage & residential cartilage


ACI With Cyst Formation

11 months
27 months
39 months
45 months

Non-Repair Site Complications

• Adhesions
• New lesions

Adhesions

Asymptomatic adhesion after ACL reconstruction

Pre-operative
3 Months

Adhesions

Postoperative MR 3 months after patellar ACI & tibial tuberosity osteotomy

Adhesions

Stiffness & catching 2.5 weeks after patellar & femoral ACI’s with tibial tuberosity osteotomy

Scope courtesy of Tom Minas, MD BWH Cartilage Repair Center
New Injury to Native Cartilage

Variable MR Appearance of ACI

Repair Tissue Type

Poor Tissue Quality

T2 Mapping - validation

* T2 maps in a horse model differentiated microfracture from transplanted hyaline cartilage (OATS) and correlated with histology*
**T2 - Clinical**

- T2 information may be obtained using spin echo or gradient echo techniques. Arrows mark site of MACI.

![T2 map – spin echo using 6 echos flip angle 180°](image1)

![T2 map – gradient echo using 6 echos flip angle 20°](image2)


**dGEMRIC - validation**

- dGEMRIC correlated with GAG in microfracture repair tissue in goat model.*
- T2 map did not correlate with biochemistry.*


**ACI dGEMRIC Measurement of GAG**

Gillis, et al. Invest Radiol 2001;12; p743-8

- 2 months post-op
- 1.5 years post-op

![ACI dGEMRIC Measurement of GAG](image3)

*Courtesy of D. Burstein, PhD BiDMD, Boston

**dGEMRIC - Clinical**

- 3D – dual flip angle T1 maps
- dGEMRIC demonstrates lower T1 in the MACI repair (arrows) postcontrast MR following ionic Gd-DTPA indicating GAG content of repair tissue is lower than native cartilage

![dGEMRIC - Clinical 3D – dual flip angle T1 maps](image4)


**Usefulness of MR in Evaluation of Cartilage Repair**

- What is the cause of symptoms?
  - adhesions
  - delamination
  - hypertrophy
  - underfilling or tissue loss
  - poor integration of repair tissue
- Assists in planning surgical intervention or alleviating patient anxiety (continue rehab.)
- Determination of repair tissue type remains a work in progress

**Close communication with Orthopedist**

- Know graft locations & clinical questions before MR
- Post-MR, preoperative working conference with orthopedist
- Post arthroscopy correlation with MR findings