Cartilage is more than a chondrocyte

- Superficial zone
- Deep zones
- Tidemark (delamination)
- Subchondral bone
The Knee is an Organ

- Articular Cartilage
- Ligaments
- Menisci
- Subchondral Bone
- Nerves
- Biomarkers
- Alignment

Current Concepts of Articular Cartilage Restoration Techniques in the Knee
Christopher L. Camp, MD, Michael J. Stuart, MD, Aaron J. Krych, MD

Clinical, functional, and radiographic outcomes may be improved in the majority of patients with articular cartilage restoration surgery; however, some patients may not fully return to their pre-injury activity levels postoperatively.

Identify & Correct

- Ligament insufficiency
- Meniscus deficiency
- Limb malalignment
Proximal Tibial Osteotomy

Many lesions asymptomatic & don’t require restoration

≤ 1 cm² Vertical walls

Homminga et al JBJS 1990
Widuchowski et al AJSM 2009

Many lesions are symptomatic, but respond to joint irrigation, loose body removal & debridement

Primum... NON NOCERE
First... DO NO HARM
Cartilage Restoration Strategies

- Marrow stimulation
- Osteochondral transfer
  - Transplantation
- Cell-based

Microfracture
Osteochondral autograft
Osteochondral allograft
Chondrocyte implant
Microfracture

Advantages

- most commonly used technique
- “original” cell-based therapy
- simplest
- low morbidity
- cost-effective
- “first-line” Rx

Nano-drilling
Microfracture

Disadvantages

- Mixed fibrocartilage repair tissue
- Best for smaller lesions
- Inferior results in older patients
- Success deteriorates with time

24 months

Menetry KSSTA 2010

Doesn’t burn any bridges?

- Deterioration of 80% over 10 years in athletes
- 44% return to sport
- Higher failure rate in patients undergoing ACI following MFX (8% vs 26%)

Minas AJSM 2009
Gobbi AAOS 2012
Mithoefer AJSM 2006

Long-term results after microfracture treatment for full-thickness knee chondral lesions in athletes

Alberto Gobbi - Georgios Karnatzikos - Mary Kammer
DOI 10.1007/s00167-013-2575-8

- 67 athletes prospectively followed
- Average 15.1 year follow-up
- 2 years: IKDC, Lysholm, Tegner
- Deteriorated with time
- 89% survival at 5 years
- 43% survival at 15 years

Smaller lesions & younger patients (<30 years) did better

Fibrocartilage @ 5 yrs
Microfracture

- Remains a viable, cost-effective, 1st-line treatment option for small, full-thickness chondral lesions & occasionally for large lesions in older, low demand patients
- Meticulous surgical technique
- Rehabilitation program compliance

2nd Look @ 1 year

600+ NHL Games
Osteochondral Autograft Transfer

Advantages
- autogeneic bone & hyaline cartilage
- replaces bone
- no risk of disease transmission
- no immune response or rejection
- best for small defects
  (natural history unknown)

Disadvantages
- technically demanding
- trauma at insertion may impair cell viability
  (Kang AJSM 2010)
- difficult to restore joint surface contour (graft height mismatch)
Osteochondral Autograft

Disadvantages
• donor site morbidity
• lack of peripheral integration
• fibrocartilage fills intertices
• not applicable for large defects ($\geq 4\text{cm}^2$

Clinical Experiences With Autologous Osteochondral Mosaicplasty in an Athletic Population
A 17-Year Prospective Multicenter Study
Prospective multicenter study in athletes
• 354 patients followed 9.6 years
• 1-4 cm$^2$ lesions
• 91% good & excellent results for femoral lesions
• 5% patellofemoral harvest morbidity

Osteochondral Autograft

• Young, high demand patients with isolated, full-thickness, chondral, or osteochondral lesions $\leq 2 - 3\text{ cm}^2$
• Results tend to be slightly better for isolated femoral condyle lesions, but remains a viable option for treating trochlear defects
17 x 16 mm = ~ 2.5 cm²

Post-op Rehab
• 6 weeks TTWB-PWB
  ➢ CPM 6-8 hrs/day
  ➢ Early quad function
  ➢ Alter-G
• 6-12 weeks
  ➢ Normalize gait
  ➢ Closed chain strength
• 4-6 months
  ➢ Elliptical for cardio
  ➢ Running Analysis
  ➢ Gradual return to sport

Allograft Plug
Autograft Plug

creeping substitution
fully incorporated
3 year follow-up → completed 2 years of competitive sports

No donor site symptoms

Osteochondral Allograft Transplantation

Advantages
- bone & mature hyaline cartilage
- match size & surface contour
- nutrition by synovial fluid diffusion
- aneural & relatively avascular
- immunoprivileged tissue
Osteochondral Allograft

**Disadvantages**
- cartilage cell viability
- disease transmission
- availability
- expense
- limited time to implant graft

Osteochondral Allograft

58 patients (38 years)
Mean 22 year f/u (range 15 to 32)
Survivorship (3 graft failures)
- 91% at 10 years
- 84% at 15 years
- 69% at 20 years
- 59% at 25 years
Surviving grafts had good function
HSS score = 86

Distal Femoral Fresh Osteochondral Allografts

Follow-up at a Mean of Twenty-two Years
- 122 patients (129 knees) avg age 33 years
- 13.5 year follow-up
- Survivorship:
  - 82% at 10 years
  - 66% at 20 years
- Age > 30 risk factor for failure
- 2/3 success at 20 years
Osteochondral Allograft

- **Large**, articular defects of the femoral condyle, trochlea, or patella in young, high-demand patients
- Prior **failure of microfracture** or ACI is not a contraindication
- Donor tissues must be **size matched** to individual patients based on x-ray, CT, or MRI measurements

---

22 year old male

Right Knee Pain

- Motocross accident
  - stuck out right leg rounding a corner
- “Medial collateral ligament sprain”
- Persistent lateral knee pain & catching
- Arthroscopic surgery elsewhere
  - lateral femoral condyle fracture debridement
Treatment

- Right knee arthroscopy
  ✓ 20 x 25 mm full thickness cartilage loss involving the lateral femoral condyle

- Open lateral femoral condyle osteochondral allograft transplantation
18 months post-op

28 year old soccer player

OCD
Medial Femoral Condyle & Trochlea

- activity-related anterior pain
- occasional catching
- mild swelling
- refractory pain
Physical Examination

2 years later (persistent symptoms after microfracture)

- pain with squatting
- trace effusion
- medial joint line tenderness
- moderate retropatellar crepitus
- normal knee stability
Treatment

• arthroscopic examination
• trochlea & medial femoral condyle osteochondral allograft transplantations
MRI - 1 Year Postop

Outcome

3 Years
- no pain
- no retropatellar crepitus
- no effusion
- symmetric knee range of motion
- light jogging & sports with his children

Autologous Chondrocyte Implantation
Cell-Based Techniques

Autologous Chondrocyte Implantation (ACI)
- FDA approved for *unipolar focal femoral* defects
- 2 stage
  - *1st stage* biopsy
  - *2nd stage* implantation

Chondrocyte Implantation

**Advantages**
- Durable repair *(Peterson AJSM 2010)*
  - 224 knees- average lesion size 5.3 cm²
  - Follow-up 10-20 years after implantation (mean, 12.8 years)
  - Tegner score 8.2
  - 92% satisfaction

Chondrocyte Implantation

**Disadvantages**
- Invasive
- 2 stage
- Lengthy rehabilitation
- Reoperation 42% at 9 year follow-up *(Mosley AJSM 2010)*
- Expensive
224 patients
- Defect 5.3 cm²
- Mean 13 year follow-up
- Lysholm 69.5
- Tegner score 8.2
- 92% satisfaction
- Worse results bipolar lesions

210 patients
- 12 year mean follow-up
- 71% survivorship
- 75% improved function
- Better results with HTO
- Worse results following MFX

How many athletes return to sport after ACI?
- G/E results in 72-96% of athletes
- 33-96% return to high impact sports
  - Soccer players 33%
    - Competitive 83%
    - Recreational 16%
  - Adolescent athletes 96%
- Best rate of return: single lesion, age <25, short preop interval
Articular Cartilage Treatment in High-Level Male Soccer Players
A Prospective Comparative Study of Arthroscopic Second-Generation Autologous Chondrocyte Implantation Versus Microfracture

- 41 professional soccer players
- 7.5 year follow-up
- 21 MFX vs 20 second generation ACI
- 86% return to sport ACI vs 80% MFX
- MFX deteriorated with time
- ACI more durable

Chondrocyte Implantation

- Reliable technique that can be used to treat large, unifocal or multifocal cartilage injuries in high-demand patients.
- Fills defects with hyaline-like cartilage and is not limited by lesional geometry
- Advanced graft coverage techniques, such as the collagen-covered ACI procedure.

18 year old male with bilateral knee pain

- Former football player
- Progressive anterior knee pain and swelling x 3 years
- Occasional catching & give way
- Pain now level 8 on a 10 point scale
ACI & BioGide

Juvenile Particulated Chondral Allograft

- 1 stage
- Early data encouraging*
- Long-term follow-up needed

*Tompkins 2013 Arthroscopy

Does it work?

6 months

2/2/2016
Subchondral Edema

before

Resolved
after 1 year

Increasing Mechanical Symptoms
@ 16 months

Cartilage Overgrowth

Symptomatic Hypertrophy
Multi-center retrospective study
- 25 patients avg age 37 with 2 yr follow-up
- Mean lesion size 2.7 cm²
- 8 biopsies hyaline/fibrocartilage mix
- T2 weighted MRI values approaching surrounding articular cartilage
- Good clinical outcomes

NeoCart
Phase 3 Investigational Trial
- Arthroscopic cartilage biopsy
- Cells expanded
- Embedded in type I collagen scaffold
- Incubated in Tissue Engineering Processor
- Neocartilage construct is shipped when biomarkers indicate chondrocyte function
Lateral Femoral Condyle full thickness articular cartilage lesion

Lesion Preparation
NeoCart Preparation

CT3 Bioadhesive Application

Initial lesion
Time zero implantation
Phase II trial
RCT with MFX (21:9)
Safety similar to MFX
Greater clinical efficacy
> more responders
Cartiform

• Cryopreserved viable chondral allograft
• Single step procedure
• 2 year shelf life at -80°C
• Easily cut to desired size and shape
• Pores serve multiple purposes
  › Increase flexibility
  › Facilitate mesenchymal stem cell migration into Cartiform following marrow stimulation procedure

24M with recurrent lateral patellar dislocation

• Symptomatic medial patellar facet chondral lesion
• 20 x 20 mm lesion
• MPFL reconstruction
• Cartiform
The best technique for articular cartilage restoration depends on age, activity level, lesion location & size.

Common goals are symptom relief, improved activity level & possibly delay of posttraumatic arthritis... maybe return to sports.
Conclusions

- *First*, do no harm
- *Second*, correct all associated problems: menisci, ligaments, subchondral bone & limb alignment

Conclusions

- Fill articular defects with either fibrocartilage (microfracture), *hyaline-like* cartilage (ACI), or *hyaline* cartilage (OAT, OCA)

Conclusions

- Careful patient selection, precise technique & postoperative rehabilitation are essential for clinical & functional outcomes.