Techniques for cartilage restoration

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Cartilage properties

Tissue with special **biomechanical** and **biochemical** characteristics containing adequate extracellular matrix

1. It can afford heavy mechanical loads without permanent structural damage

2. Provides support to muscles and ligaments

3. Protects articular surface during motion

4. Has crucial role in bone growth and remodeling
Types of cartilage

- Hyaloid
- Elastic
- Fibrous
Epidemiology of cartilage damage

- Curl et al. described 53,569 hyaline cartilage lesions in 19,827 patients undergoing knee arthroscopy\(^1\)

- A survey of 993 consecutive knee arthroscopies demonstrated evidence of articular cartilage abnormality in 66\%\(^2\)

- Articular cartilage defects of the femoral condyles have been observed in up to 50\% of athletes undergoing ACL reconstruction\(^3\)

A: partial thickness defect

B: full thickness defect
Two major problems

The **first** is to fill the defect void with a tissue that has the same mechanical properties as articular cartilage.

The **second** is to promote successful integration between the repair tissue and the native articular cartilage.
Twenty-three guidelines have been developed for the treatment of hip and/or knee OA, based on opinion alone, research evidence or both. Although this suggests that a core set of recommendations for treatment exists, critical appraisal shows that the overall quality of existing guidelines is sub-optimal, and consensus recommendations are not always supported by the best available evidence.

Non-pharmacological
- acupuncture
- manual therapy
- physical therapy
- devices (orthotics)
- education
- self-management
- weight loss
- TENS
- thermal modalities
- nutraceuticals (chondroitin)

Pharmacological
- Acetaminophen
- Topical NSAIDs
- Cox-2 inhibitors
- Opioids
- Glucosamine
- Chondroitin sulphate
- Diacerhein
- molecular HA (Hylan)

Surgical
- Arthroscopic lavage Knee
- Arthroscopic debridement
- Patellar resurfacing Knee
- Osteotomy Knee
- Joint distraction
- TJR Both
- Knee aspiration
- Knee fusion
The first abnormality seen in osteoarthritic cartilage is oedema, which is secondary to disruption of the macromolecular framework and degradation of aggrecan.

Table I. Changes in articular cartilage after injury, in osteoarthritis and with ageing³

<table>
<thead>
<tr>
<th>Feature</th>
<th>Reversible injury</th>
<th>Osteoarthritis</th>
<th>Ageing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cartilage mass</td>
<td>Hypertrophy</td>
<td>Hypertrophy, erosion</td>
<td>No change</td>
</tr>
<tr>
<td>Cartilage topographic distribution</td>
<td>Focal</td>
<td>Focal, heterogenous</td>
<td>General, all layers</td>
</tr>
<tr>
<td>Cartilage water</td>
<td>Oedema</td>
<td>Oedema</td>
<td>Dehydration</td>
</tr>
<tr>
<td>Cartilage collagen</td>
<td>Reversible deformation</td>
<td>Degradation</td>
<td>Increased advanced glycation end-products</td>
</tr>
<tr>
<td>Cartilage proteoglycan</td>
<td>Reversible depletion</td>
<td>Irreversible depletion</td>
<td>Reduced synthesis</td>
</tr>
<tr>
<td>Cartilage matrix degeneration products</td>
<td>Resorption</td>
<td>Accumulative, collagen, proteoglycan etc.</td>
<td>Accumulative: oxidation, glycation, amyloid</td>
</tr>
<tr>
<td>Cell activity</td>
<td>Reversibly increased</td>
<td>Increased activity and proliferation</td>
<td>Reduced</td>
</tr>
<tr>
<td>Synovium</td>
<td>Mild focal superficial inflammation</td>
<td>Mild focal superficial inflammation</td>
<td>Atrophy</td>
</tr>
<tr>
<td>Bone</td>
<td>No change</td>
<td>Subchondral remodelling</td>
<td>Osteopaenia</td>
</tr>
</tbody>
</table>
ASPECTS OF CURRENT MANAGEMENT

The assessment of early osteoarthritis

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S. E. Gwilym,
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From the Nuffield Orthopaedic Centre,
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Synovium

MRI
Synovial biomarkers
hyaluronan, COMP, CRP
Synovial interstitium
Lymphatic
Monocyte macrophage system
Blood
Clinical measurement

Relative sensitivity of imaging modalities to histological change

MRI
CT arthrography
HF ultrasound
Plain radiography

dGEMRIC
Biomarkers of synthesis/degradation of aggregan, collagen type II, COMP and other matrix proteins and proteoglycans, CRP

Synovial fluid
Superficial zone
Mid-zone
Deep zone
Tidemark
Calcified cartilage
Subchondral bone

OARSI histological grade
Progression of osteoarthritis

Normal
Gedema uneven surface
Surface discontinuity
Erosion
Deformation Osteophyte

Surface fibrillation
Vertical fissures
Denudation
Microfracture
Fibrocartilage Sclerosis
Gadopentetate dimeglumine disperses inversely with the amount of GAG in cartilage; thus, normal articular cartilage should have a low concentration, and damaged cartilage should have a high concentration.
Treatment options

1. Arthroscopic lavage & debridement
2. Bone marrow stimulation
3. Cell-based therapy
4. Osteochondral autograft transfer
5. Scaffolds
6. Allografts
7. Osteotomy

Tibiofemoral compartment #
Patellofemoral compartment
2 groups (3000ml) instead (250ml) of fluid irrigation
Beneficial only in patients with early OA and crystals
The combination of both procedures show efficacy in reducing WOMAC pain scores and improving SF-36 PCS scores over a six month period.
In patients with osteoarthritis of the knee, neither arthroscopic lavage nor arthroscopic débridement was better than a placebo procedure for reducing pain or improving function.
No evidence that removal of loose debris, cartilage flaps, torn meniscal fragments, etc have any pain relief or functional benefit in patients that have joint space narrowing on standing radiographs.

3 indications only:

- removal of loose body
- meniscectomy
  \[\text{True mechanical symptoms}\]
- anterior osteophyte (to improve extension)
Bone marrow stimulation

Symptomatic, focal high-grade chondral lesions of the weightbearing femoral condyles, trochlea, and patella in active patients

Incidental cartilage lesions

A defect size of $<4 \text{ cm}^2$

A short preoperative duration of symptoms (optimally, less than 12 months)

Optimal patient age should be $< 45$ years-old

Surgical technique

- Debridement, with use of an arthroscopic shaver, of any loose cartilage flaps to create a stable peripheral cartilage margin
Surgical technique

- débridement of the calcified cartilage layer with use of a curet to provide manual feedback control
Surgical technique

- the adequate depth of subchondral bone penetration and width of osseous bridges between the individual microfracture holes
Surgical technique

- the adequate depth of subchondral bone penetration and width of osseous bridges between the individual microfracture holes

![Diagram showing microfracture holes with a 3-4 mm spacing](image)
Surgical technique

- adequacy of the microfractures by noting the release of fat droplets and blood from the individual holes
The initially formed blood clot as produced by microfracturing is protected by the collagen membrane.
Surgical technique

- technique for microfracture of patellar lesions
## Rehabilitation

### Femoral condyle

<table>
<thead>
<tr>
<th>Phase</th>
<th>Weight Bearing</th>
<th>Brace</th>
<th>ROM</th>
<th>Therapeutic Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I 0-8 weeks</td>
<td>Touchdown weight bearing (20-30%) for the first 6-8 weeks</td>
<td>None</td>
<td>Use of a CPM for 6-8 hours/day set at a rate of 1 cycle/minute, advancing 10° daily - begin at a level of flexion that is comfortable for the patient - advance to full flexion as tolerated</td>
<td>Passive stretching/exercise for the first 6 - 8 weeks, quad/hamstring isometrics</td>
</tr>
<tr>
<td>Phase II 8-12 weeks</td>
<td>Gradual return to full weight</td>
<td>None</td>
<td>Gain full and pain-free</td>
<td>Progressive active strengthening</td>
</tr>
<tr>
<td>Phase III 12 weeks and beyond</td>
<td>Full</td>
<td>None</td>
<td>Full and pain-free</td>
<td>Return to full activities, including cutting, turning, and jumping</td>
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### Troclear-patellar defect

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<th>ROM</th>
<th>Therapeutic Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I</td>
<td>Weight bearing as tolerated</td>
<td>Locked 0 - 40°</td>
<td>Use of a CPM for 6-8 hours/day - begin at a rate of 1 cycle/minute, ranging from 0 - 40°</td>
<td>Passive stretching/exercise for the first 6 - 8 weeks, quad/hamstring isometrics</td>
</tr>
<tr>
<td>0 - 8 weeks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase II</td>
<td>Full</td>
<td>None</td>
<td>Gain full and pain-free</td>
<td>Begin closed chain activities, emphasizing a patellofemoral program</td>
</tr>
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<td></td>
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Clinical studies

The overall clinical results of the microfracture arthroplasty have shown improved knee function in 70% to 95% of patients.


Who is the ideal candidate for microfracture?

1. As a first line treatment
2. Isolated, well-contained lesion
3. Less than 12 months after the injury
4. Femoral condyle > troclear
5. Less than 4cm²
6. Less than 40 years
7. Low body mass index
8. Complied with the rehab program
ACI is ideal for symptomatic, unipolar, full thickness, or nearly full thickness chondral or shallow osteochondral defects.

Commonly, patients have failed previous treatments.

Occasionally, larger symptomatic lesions are indicated as a first line treatment.
Healthy biopsy taken from non-load bearing region

Chondrocytes released by enzymatic digestion

Chondrocytes expanded in culture

Suspension of cultured autologous chondrocytes prepared

Defect debrided back to healthy cartilage

Periosteal graft sutured over defect

Cultured autologous chondrocytes injected under periosteal flap
Typical P-ACI: surgical technique
Osteochondral autograft transfer

- patients less than 50 years
- full-thickness focal chondral defects
- < 4 cm²
- femoral condyles
Cylindrical plugs of osteochondral tissue removed from non-load bearing regions of articular cartilage

Osteochondral plugs transplanted into debrided full-depth defect
Osteoarthritic degenerative changes of Fairbank grade I or II were observed in 43% of the affected joints.

The average size of the chondral defects in treated knees was 2.0 cm.

Only 8% of the athletes rated the postoperative knee function and symptom scores as being worse than before the procedure.
The ideal patient is less than 50-60 years old and has good joint environment:

Well contained focal defects
No more than 2-3 lesions
No ligamentous laxity
No generalized degeneration
Chondral scaffolds are usually monophasic, even though some have a bilayer structure to better follow the biphasic composition of the osteochondral unit.

The most commonly used chondral matrices consist of collagen and hyaluronic acid.
Matrix- assisted ACI: surgical technique
53 patients with symptomatic isolated or multiple localized osteochondral defects (2–10 cm²)

Mean age was 40 years (18–60 years).

Satisfying outcomes on 17 patients who were reevaluated 5 years after surgery. At 60 months, MRI scans showed complete integration with the surrounding native cartilage without any sign of detachment or bone marrow edema in 15 cases.
This study shows that mid-term results of ACI in high performance patients are not as good as have been reported with other similar technologies. Reasons for failure can be:

- prolonged rehabilitation
- multiple surgical interventions
- patient age and
- large defects

The ideal candidate for ACI is a young and fit patient with high preoperative IKDC scores and no previous operations who is <12 months symptomatic and has an isolated and small-sized cartilage defect.
Biphasic scaffolds

Biphasic scaffolds for osteochondral regeneration:

**Trufit**: bilayer porous PLGA-calcium-sulfate biopolymer

**Maioregen**: nanostructured biomimetic scaffold with a porous 3-dimensional tri-layer hydroxyapatite-collagen composite structure, mimicking the osteochondral anatomy
2 years postoperatively
Osteochondral allografts

- Availability
- size matched to the patient
- accredited tissue banks
- disease transmission
- high cost
- better fresh (viable cartilage)

“sell allografts”
“bipolar allografts”
Technical aspects

A **plug graft** is, a round graft prepared by commercially available instruments that form grafts between 15 and 35 mm in diameter.

**Shell grafts** are more complex geometric shapes that must be prepared by hand. These are utilized for resurfacing the femoral condyle patella and tibial plateau.
- 25 FOCA transplantation in femoral condyle
- average age 35 years (range, 17-49 years)
- follow-up: 35 months (range, 24-67)
- 84% satisfaction
- X-ray: 22 of the grafts (88%) were incorporated into host bone
Meniscal scaffolds

- > 25% loss of meniscal tissue due to trauma or surgical intervention
- no or minimal chondral damage
- Menaflex or Actifit
Osteotomy

Indications

Malalignment associated with unicompartmental OA, cartilage or meniscal lesions, and ligament instability

Preoperative MRI or concominant arthroscopy to assess the articular surface and meniscus of the contralateral compartment.

Contraindications

meniscal lesion in the contralateral compartment decreased < 90 degrees of flexion or more than 15 degrees of flexion contracture, tibial subluxation greater than 1 cm, obesity, smoking and compromised bone stock
Medial opening-wedge HTO

A medial opening HTO is usually performed when a severe varus deformity is present with proximal tibial malrotation,

Also when we need to correct tibial slope in case of associated ligament laxity.

preservation of the tibiofibular joint, no risk of injury to the peroneal nerve, no loosening of posterolateral structures, no limb shortening and easier adjustment of the tibial slope.
Performed for OA patients with no morphotype alterations and with light or moderate deformity. However, it is more difficult to change the tibial slope.

Does not require bone, grafting, allows earlier weight-bearing, has less risk of nonunion, and loss of correction.

The need for fibular osteotomy increases the risk of nonunions and peroneal nerve palsy.
For the varus-producing osteotomies, we aim to move the mechanical axis to a point 48–50% across the width of the tibial plateau from lateral to medial, mostly by means of a DFO and only in select cases by a medial closing-wedge HTO.
At 5 years, 70–90% of patients report satisfactory outcomes, which decreases to 50–70% at 15 years.


Saragaglia D, Blaysat M, Inman D, Mercier N. *Outcome of opening wedge high tibial osteotomy augmented with a Biosorb wedge and fixed with a plate and screws in 124 patients with a mean of ten years follow-up*. Int Orthop 2010 35:1151–1156.
This combined procedure provides a safe treatment option for younger patients with medial knee OA and varus alignment with significant clinical improvement at 5 years.

However, overall graft survival and cartilage infill were poor (MRI study).
Conclusions

Young patients with cartilage lesions or early osteoarthritis represent a challenging population due to a combination of high functional demands and limited treatment options.

Conservative measures such as injection and physical therapy can provide short-term pain relief but are only palliative in nature.
Joint replacement, a successful procedure in the older population, is controversial in younger patients, who are less satisfied and experience higher failure rates.

Specifically patients younger than 40 can only expect a 50% chance of good and excellent Knee Society function scores and a revision rate of 12.5% at 8 years.
Conclusions

Cartilage repair techniques with/or without osteotomy therefore, appears as a potentially promising treatment alternative for the young patient with disabling symptoms