Meniscus, Articular Cartilage Injury and the Degenerative Knee in the Athlete

LTC ANTHONY E. JOHNSON, MD, FAAOS
CHAIRMAN, DEPARTMENT OF ORTHOPAEDICS & REHABILITATION
CO-CHAIRMAN, U.S. ARMED FORCES SPORTS, MEDICAL ADVISORY GROUP
TEAM PHYSICIAN, USA PARALYMPIC BASKETBALL

ACSM Team Physician Course
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"The warrior above all others prays for peace, for it is the warrior above all others who must suffer and bear the deepest wounds and scars of war"
Background

• 1887: Sutton described the meniscus as “the functionless remains of a leg muscle.”
  
  Bland-Sutton J. Ligaments: Their Nature and Morphology. 2nd ed. London, UK: HK Lewis; 1887

• 1948: Fairbanks appreciate that “meniscectomy is not wholly innocuous”


• The critical importance of the meniscus of the knee joint is now better understood

"The warrior above all others prays for peace, for it is the warrior above all others who must suffer and bear the deepest wounds and scars of war"
Epidemiology

• Overall incidence unknown
  – Surgical incidence is 61:100,000 annually
    • Most common orthopedic surgical procedure (US)
      – estimated 850,000 patients each year
    • 1/3rd of meniscal tears associated with ACL injury
• Overall male-to-female incidence 2.5:1
  – Peak incidence of meniscal injury
    • Males: 31-40 years vs Females: 11-20 years
• Rate of degenerative meniscal tears is 60%
  – Age > 65


"The warrior above all others prays for peace, for it is the warrior above all others who must suffer and bear the deepest wounds and scars of war"
Key Points

• Acute knee injuries with ACL intact
  – Medial meniscal injury is 5 times more likely than lateral
• Acute knee injuries with disrupted ACL
  – Lateral meniscus more likely to be involved
• Chronic ACL deficient knee
  – Lateral meniscal injury is more likely than medial
• Repetitive deep squatting
  – Medial meniscus most likely to be injured (20:1)

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“The warrior above all others prays for peace, for it is the warrior above all others who must suffer and bear the deepest wounds and scars of war”

San Antonio Military Medical Center

Biology of the Meniscus

- Form
- Function
- Healing Potential

“In normal joint homeostasis, there is a healthy equilibrium between smooth cartilage, subchondral bone, synovial fluid, synovium, intact menisci and ligaments”

Functions of the Menisci

- Distribute load across the knee joint
  - 2-4x body weight during walking
  - 6-8x body weight during running
- Axial compression is converted to “hoop stress”
  - Decreases friction by 20%
  - Increases contact area by 70%
  - LM carries majority of load while MM distributes evenly between meniscus and articular cartilage
  - Even torn meniscus will carry load as long as peripheral circumferential fibers intact
- Distributes contact
  - Force synovial fluid into articular cartilage during compression


"The warrior above all others prays for peace, for it is the warrior above all others who must suffer and bear the deepest wounds and scars of war"
Functions of the Menisci

- Contributes to stability of knee
  - Wedge shape
    - Deepens “socket” of the tibial plateau
    - Limits translation of femur on tibial plateau
      - Secondary stabilizer
  - Forced posteriorly in flexion, anteriorly in extension of the knee
    - Reduce stresses on the ACL
  - Removal of menisci does NOT preclude normal motion, but
    - Increase wear on articulating surfaces
    - Increase chance of developing degenerative joint disease

"The warrior above all others prays for peace, for it is the warrior above all others who must suffer and bear the deepest wounds and scars of war"
Neuro-Vasculature of the Menisci

• Vascular
  – Peripheral 1/3rd vascular
    • Supplied by the geniculate arteries
  – Inner 1/3rd avascular
    • Relatively thin
    • Nourished through synovial fluid
  – Central 1/3rd intermediate
    (variable)

• Neuro
  – Free nerve endings
    • Peripheral & Central 1/3rd
  – Encapsulated mechanoreceptors
    • Anterior and posterior horns


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History: the Key to Diagnosis

• Twisting on planted foot
  – Inertial forces or external forces
• Acute effusion in acute injury
• Waxing and waning course with pain and effusion intermittently in chronic injury
• The older the patient, the less likely that history will be revealing
  – More likely to occur with trivial trauma
  – Difficult to distinguish from DJD

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## Physical Exam

<table>
<thead>
<tr>
<th>Finding/Test</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint Line Tenderness</td>
<td>71%</td>
<td>27%</td>
</tr>
<tr>
<td>McMurray</td>
<td>58.5%</td>
<td>93.4%</td>
</tr>
<tr>
<td>Apley</td>
<td>58%</td>
<td>80%</td>
</tr>
<tr>
<td>MRI</td>
<td>75-87%</td>
<td>87-93%</td>
</tr>
</tbody>
</table>
Grading of Meniscal Tears: MRI

- I: globular changes
- II: linear changes not to margin
- III: linear to sup/inf margin
- IV: complex linear changes

- Only grade III and IV visible on arthroscopy

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Baker’s Cyst and the Meniscus

- **Stone**
  - 1760 MRI’s
    - 238 Baker’s cysts (13.5%)
      - 85% had meniscal tears
        » 94% medial meniscus
  - **Sansone**
    - 1001 MRI’s
      - 4.7% Baker’s cysts
      - 83% meniscus tear
      - 43% articular cartilage


"The warrior above all others prays for peace, for it is the warrior above all others who must suffer and bear the deepest wounds and scars of war"
The Use of MRI in Evaluation of Knee Injuries

<table>
<thead>
<tr>
<th></th>
<th>MM</th>
<th>LM</th>
<th>ACL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>70-100%</td>
<td>55-90%</td>
<td>91-100%</td>
</tr>
<tr>
<td>Specificity</td>
<td>55-97%</td>
<td>94-98%</td>
<td>99-100%</td>
</tr>
<tr>
<td>PPV</td>
<td>81-98%</td>
<td>90-95%</td>
<td>91-100%</td>
</tr>
<tr>
<td>NPV</td>
<td>86-100%</td>
<td>70-97%</td>
<td>99-100%</td>
</tr>
</tbody>
</table>

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Value of MRI as Diagnostic Tool

- Studies do NOT prove it superior to composite clinical exam
- Many false positives appear
- MRI has high NEGATIVE predictive value
- Sensitivity and specificity keep getting better as technology improves
- How will MRI result change treatment?
  - Helps with planning procedure

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Meniscal Injuries Treatment

- Nonoperative (Aggressive Nonsurgical)
- ROM, Quad strengthening
- Bracing (hinged knee brace)
- Continue sport specific drills when tolerable

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Non-Operative Study Results

- Review of 3612 arthroscopies
  - 80 “stable” tears (<3mm movement)
    - 70 were longitudinal, 10 were radial
  - Only 6 needed subsequent surgery
    - 4 of which had had additional trauma
  - 32 patients had “second look” surgery
    - 17/22 (77.2%) longitudinal tears healed
    - 0/6 radial tears healed


"The warrior above all others prays for peace, for it is the warrior above all others who must suffer and bear the deepest wounds and scars of war"
### Results Without Surgery

<table>
<thead>
<tr>
<th>Lat Meniscus</th>
<th>69% healed completely, 18% healed partially</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial Meniscus</td>
<td>58% healed completely, 0% healed partially</td>
</tr>
<tr>
<td>Ant. Cruc. Ligment</td>
<td>80% healed “satisfactorily”</td>
</tr>
<tr>
<td>Post Cruc. Ligament</td>
<td>3/7 (40%) healed “satisfactorily”</td>
</tr>
</tbody>
</table>

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Menisectomy Shortens NFL Careers

- Menisectomy findings
  - Quick recovery/return to play
  - Significantly shortened career

- NFL players with history of menisectomy
  - Reduced career by 1.5 seasons
  - Played about 23 fewer games

Brophy RH, Gill CS, Lyman S, et al. Effect of ACL reconstruction and menisectomy on career length in NFL athletes: A case control study. 2009 AOSSM

"The warrior above all others prays for peace, for it is the warrior above all others who must suffer and bear the deepest wounds and scars of war"
Meniscus Allograft Transplantation

- Performed for ~ 20 years
  - MANY unanswered questions
- Indications (must meet all):
  - Younger than 55 years and physically active
  - < 50% a meniscus or a tear that cannot be repaired
  - Persistent activity-related pain
  - Knee with stable ligaments and normal alignment
  - No or minimal knee arthritis
  - Not obese


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MAT – Short Term Results

- **USNA Study**
- **N=30**
- **31 procedures**
- **1997-2004**

**Outcomes:**
- Overall, between 21% and 55% of transplants fail within 10 years
- Lateral meniscal transplants generally more successful than medial meniscus
Osteoarthritis

- Osteoarthritis (OA) affects nearly 27 million people in the United States
  - The most common cause of disability in adults
  - Imposes an estimated $2,600 - $7,500 in out of pocket expense per person per year for treatment
  - Accounted for 25.1% of the 44.2 million non-injury ambulatory care visits in 2004

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### Causes of Disability Among US Adults

<table>
<thead>
<tr>
<th>Cause of Disability</th>
<th>Number (in millions) among U.S. adults reporting a disability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arthritis</td>
<td>8.6</td>
</tr>
<tr>
<td>Back or Spine Problems</td>
<td>7.6</td>
</tr>
<tr>
<td>Heart Trouble</td>
<td>3</td>
</tr>
<tr>
<td>Mental or Emotional Problem</td>
<td>2.2</td>
</tr>
<tr>
<td>Lung or Respiratory Problem</td>
<td>2.2</td>
</tr>
<tr>
<td>Diabetes</td>
<td>2</td>
</tr>
<tr>
<td>Deafness or Hearing Problem</td>
<td>1.9</td>
</tr>
<tr>
<td>Stiffness or Deformity of Limbs/Extremities</td>
<td>1.6</td>
</tr>
<tr>
<td>Blindness or Vision Problems</td>
<td>1.5</td>
</tr>
<tr>
<td>Stroke</td>
<td>1.1</td>
</tr>
</tbody>
</table>


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Osteoarthritis

- The burden of degenerative OA in an older population vs. OA caused by a traumatic injury more common in a younger population has not yet been fully differentiated
  - Impact of OA on morbidity from injury and days of work lost in a young and middle-aged population is likely underestimated
- An estimated that 12% of symptomatic OA is attributable to post-traumatic OA (PTOA) of the hip, knee, or ankle
  - Aggregate financial burden of $3.06 billion
  - Or 0.15% of the total U.S. health care direct costs


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Osteoarthritis

• Within the military, OA is the most common cause of disability among service members who are medically separated from active duty
  – This represents a spectrum of service members from the young enlisted individual, the most commonly injured demographic in combat, to the older senior ranking individual with degenerative OA after a career of military service
  – Our current Overseas Contingency Operations has placed a large number of young service members at risk of traumatic injury
  – Therefore, this end of the spectrum is of great importance as military health care providers see younger combat wounded individuals with joint injuries


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Musculoskeletal DNBI

• In contrast to the 1400 Warriors lost to the fight because of amputation consider:
  – ACL injury: 25,000 in the same time period
  – Chondral injury: 30,000
  – Shoulder labral injury: 20,000


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So What? These are Sports Injuries.

- ACL tear sustained:
  1. Reacting to indirect fire in Iraq
  2. Falling down mountain in Afghanistan
  3. Pick up basketball game on R&R

All keep warriors out of the fight.

Repertive loading of articular cartilage at physiological levels of stress (1 MPa) harmful to superficial tangential zone cells, peak at 6hrs


1 MPa = 145 psi

---

There appears to be a critical threshold stress (15-20 MPa) that causes cell death.


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Proposed Mechanisms of Chondrocyte Death by Orthopaedic Subspecialty

It's Autophagy

It's Apoptosis

It's Necrosis

Sports Med

Trauma

Total Joint

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Prevalence of Articular Cartilage Lesions

- 31,516 Knee Arthroscopies
  - 53,569 articular cartilage lesions in 19,827 patients
    - 63% knees with at least one chondral lesion
      - Avg 2.7 lesions per knee
      - 20% full thickness lesions
      - 5% in patients less than 40 years of age
    - No associated ligamentous or meniscus pathology in 36.6% of patients


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PTOA After ACL Reconstruction

- 43% OA at 11.2 years
  

- 72% OA at 7 years
  

- 11% OA at 2-9 years
  

- Different methods used to evaluate osteoarthritis

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Composition of Articular Cartilage

- **Hyaline Cartilage**
  - Ends of long bones (1-5 mm thick)
  - Avascular
  - Aneural

- **Cellular – chondrocytes (10% of volume)**

- **Extracellular Matrix**
  - Organic – collagen (type II) (10-30% of weight) & proteoglycans (3-10% of weight)
  - Water (most abundant component), inorganic salts, glycoproteins, lipids (60 - 87%)

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Tire Analogy

- Tread of a tire = articular cartilage

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TABLE 2
Interrater Agreement for 31 Lesions With Grade 2 and Grade 3 Lesions Combined

<table>
<thead>
<tr>
<th>Location</th>
<th>Expected Agreement</th>
<th>Observed Agreement</th>
<th>( \kappa )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral articular lesions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Femoral condyle</td>
<td>0.55</td>
<td>0.94</td>
<td>0.86</td>
</tr>
<tr>
<td>Tibial plateau</td>
<td>0.61</td>
<td>0.81</td>
<td>0.51</td>
</tr>
<tr>
<td>Patellar</td>
<td>0.58</td>
<td>0.93</td>
<td>0.80</td>
</tr>
<tr>
<td>Trochlear</td>
<td>0.67</td>
<td>0.90</td>
<td>0.71</td>
</tr>
<tr>
<td>Medial articular lesions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Femoral condyle</td>
<td>0.56</td>
<td>0.93</td>
<td>0.84</td>
</tr>
<tr>
<td>Tibial plateau</td>
<td>0.79</td>
<td>0.87</td>
<td>0.34</td>
</tr>
<tr>
<td>Patellar</td>
<td>0.56</td>
<td>0.94</td>
<td>0.87</td>
</tr>
<tr>
<td>Trochlear</td>
<td>0.67</td>
<td>0.92</td>
<td>0.76</td>
</tr>
</tbody>
</table>

TABLE 3
Interrater Agreement for 22 Lesions Without Grade 2 and Grade 3 Lesions Combined

<table>
<thead>
<tr>
<th>Cartilage Grade</th>
<th>Expected Agreement, %</th>
<th>Observed Agreement, %</th>
<th>( \kappa )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>3.4</td>
<td>0.45</td>
</tr>
<tr>
<td>2</td>
<td>13.2</td>
<td>22.3</td>
<td>0.41</td>
</tr>
<tr>
<td>3</td>
<td>24.9</td>
<td>38.1</td>
<td>0.52</td>
</tr>
<tr>
<td>4</td>
<td>0.4</td>
<td>3.4</td>
<td>0.52</td>
</tr>
<tr>
<td>Overall</td>
<td>38.9</td>
<td>67.2</td>
<td>0.47</td>
</tr>
</tbody>
</table>


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**Overview of Reported Clinical Results After Microfracture**

<table>
<thead>
<tr>
<th>Clinical knee function</th>
<th>Better Results With</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-term clinical improvement rate (≤24 mo)</td>
<td>75%-100%</td>
</tr>
<tr>
<td>Long-term clinical improvement rate (&gt;24 mo)</td>
<td>67%-86%</td>
</tr>
<tr>
<td>Functional deterioration (&gt;24 mo)^a</td>
<td>47%-80%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factors</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetic resonance imaging</td>
<td>≤40 years</td>
</tr>
<tr>
<td>Complete cartilage fill</td>
<td></td>
</tr>
<tr>
<td>Poor cartilage fill</td>
<td>≤12 months</td>
</tr>
<tr>
<td>Complete peripheral integration</td>
<td>≤4 cm^2</td>
</tr>
<tr>
<td>Subchondral bone hypertrophy</td>
<td>≤30 kg/m^2</td>
</tr>
<tr>
<td>Macroscopic/microscopic repair cartilage</td>
<td></td>
</tr>
<tr>
<td>Macroscopic grading normal/near normal</td>
<td></td>
</tr>
<tr>
<td>Histology:</td>
<td></td>
</tr>
<tr>
<td>Fibrocartilage</td>
<td></td>
</tr>
<tr>
<td>Fibrohyaline hybrid tissue</td>
<td></td>
</tr>
<tr>
<td>Complication rate</td>
<td></td>
</tr>
<tr>
<td>Serious procedure-related complications</td>
<td></td>
</tr>
<tr>
<td>Failure/revision rate</td>
<td></td>
</tr>
<tr>
<td>Less than 24 mo</td>
<td>2.5%</td>
</tr>
<tr>
<td>After 24 mo</td>
<td>2%-31%</td>
</tr>
</tbody>
</table>

^aDespite deterioration, clinical function still better than before microfracture.
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"The warrior above all others prays for peace, for it is the warrior above all others who must suffer and bear the deepest wounds and scars of war.”

Improvement from baseline of the modified scales of the Cincinnati Knee Rating System. *For all scales, baseline and follow-up scores were significantly different at the .05 level (P < .0001).

Did Not Improve at 6-10 Years’ Follow-up | Improved at 6-10 Years’ Follow-up | Total
--- | --- | ---
Did not improve at 1-5 years’ follow-up | 15 (20.8%) | 3 (4.2%) | 18 (25%)
Improved at 1-5 years’ follow-up | 7 (9.7%) | 47 (65.3%) | 54 (75%)
Total | **22 (30.6%)** | **50 (69.4%)** | **72 (100%)**

*McNemar P value = 0.206.*

No improvement from baseline was defined as a negative change or no change in overall condition score from baseline to latest follow-up. Improvement was defined as a positive score change of at least 1 point from baseline to latest follow-up.


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### Characteristics of Full-Thickness Chondral Lesions

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients with acute onset of injury</td>
<td>65% (47/72)</td>
</tr>
<tr>
<td>Total surface area, cm²</td>
<td>5.2 ± 4.15</td>
</tr>
<tr>
<td>Mean</td>
<td>0.4-23.5</td>
</tr>
<tr>
<td>Range</td>
<td></td>
</tr>
<tr>
<td>Osteochondritis dissecans, % patients</td>
<td>6% (4/72)</td>
</tr>
<tr>
<td>Patients with single defect</td>
<td>83% (60/72)</td>
</tr>
<tr>
<td>Patients with multiple defects</td>
<td>17% (12/72)</td>
</tr>
<tr>
<td>Total number of defects</td>
<td>84</td>
</tr>
<tr>
<td>Defect location</td>
<td></td>
</tr>
<tr>
<td>Medial femoral condyle</td>
<td>72% (61/84)</td>
</tr>
<tr>
<td>Lateral femoral condyle</td>
<td>18% (15/84)</td>
</tr>
<tr>
<td>Trochlea</td>
<td>10% (8/84)</td>
</tr>
</tbody>
</table>


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Mosaicplasty

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Mosaicplasty

- 831 Mosaicplasties performed from Feb 1992 – Feb 2002
  - 597 Femoral Condyle
  - 118 Patellofemoral Joint
  - 25 Tibial plateau
- 92% good to excellent for femoral condyle, 87% in tibial plateau, 79% patellar/trochlear
- 92% good to excellent modified HSS scores at 3-6 years


"The warrior above all others prays for peace, for it is the warrior above all others who must suffer and bear the deepest wounds and scars of war"
Typical graft insertion forces did not significantly reduce chondrocyte viability. However, increased graft length relative to:

- The depth of the recipient hole
- Attempts to recess the graft generated higher forces
  - Which reduced chondrocyte viability


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<table>
<thead>
<tr>
<th>Factors Affecting Return to Sport After Cartilage Repair</th>
<th>MF</th>
<th>ACT</th>
<th>OAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Duration of symptoms</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Lesion size</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Lesion type</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Lesion location</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Number of previous surgeries</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Athlete’s skill level</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Concomitant procedures</td>
<td>+</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Repair tissue morphology</td>
<td>+</td>
<td></td>
<td>+</td>
</tr>
</tbody>
</table>

*Plus sign (+) indicates demonstrated effect on return to sport. MF, microfracture; ACT, autologous chondrocyte transplantation; OAT, osteochondral autograft transfer.*
TABLE 3

Comparison of Return-to-Sport Rates (in Percentages)

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Return Rate (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior cruciate ligament reconstruction</td>
<td>71 (53-81)</td>
</tr>
<tr>
<td>Meniscal repair</td>
<td>74 (56-85)</td>
</tr>
<tr>
<td>Articular cartilage repair</td>
<td>73 (66-91)</td>
</tr>
<tr>
<td>Microfracture</td>
<td>66 (44-100)</td>
</tr>
<tr>
<td>Autologous chondrocyte transplantation</td>
<td>67 (33-96)</td>
</tr>
<tr>
<td>Osteochondral autograft transfer</td>
<td>91 (86-94)</td>
</tr>
</tbody>
</table>


"The warrior above all others prays for peace, for it is the warrior above all others who must suffer and bear the deepest wounds and scars of war"
San Antonio Military Medical Center

Ultimate Goals:

"The warrior above all others prays for peace, for it is the warrior above all others who must suffer and bear the deepest wounds and scars of war"
You are not intelligent because you think you know everything, but rather because you question everything you think you know.

"The warrior above all others prays for peace, for it is the warrior above all others who must suffer and bear the deepest wounds and scars of war"
Thank you

The warrior above all others prays for peace, for it is the warrior above all others who must suffer and bear the deepest wounds and scars of war.