Enhanced Repair of Meniscal Hoop Structure Injuries Using An Aligned Electrospun Nanofibrous Scaffold Combined with a Mesenchymal Stem Cell-derived Tissue Engineered Construct

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Hoop structure injury (1)

- Symptomatic
- Limited healing (due to avascular zone injury)
- Loss of meniscal biomechanical function
- Meniscectomy in many cases

No established, effective treatments
Potential risks for OA development

e.g. radial tear
Electrospun scaffold (2)

✓ Aligned fiber
✓ Biocompatibility
✓ Slow bioabsorbability
✓ High tensile strength

poly(ε-caprolactone) (PCL)-based electrospun scaffold

Repair enhancement for radial tear using a clinically relevant in vitro meniscal explant model (3)
Hypothesis & Purpose

✓ Wrapping the meniscal tear with the cell-seeded aligned electrospun scaffold could be a potential, clinically relevant approach (3).

Feasible for the repair of hoop structure?

Test this hypothesis using a rabbit meniscal defect model

Developement of a new surgical method
Methods

Control

Medial meniscus

Scaffold

5mm width defect

Scaffold augmented w/ or w/o TEC*

TEC-Scaffold

Scaffold

Meniscus

*A scaffold-free tissue-engineered construct (TEC) derived from synovial mesenchymal stem cells (4)
Outcome Measures

• Chondroprotective effect
  - Macro & Histology for MFC cartilage

• Meniscal repair & Hoop function
  - Macro & Histology for medial meniscus
  - Ratio of meniscal uncovered area*

• Evaluation @ 4, 8, 12 wks p/o

*Meniscal uncovered area (%) = A / B x 100
(Representing “meniscal extrusion”)

Meniscal uncovered area
whole cartilage area on MTP
Macroscopic evaluation of MFC cartilage

Control & Scaffold ▷ Accelerated OA development
TEC-Scaffold ▷ Chondroprotection

Macroscopic score

<table>
<thead>
<tr>
<th></th>
<th>4w</th>
<th>8w</th>
<th>12w</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>2.0</td>
<td>2.5</td>
<td>3.0</td>
</tr>
<tr>
<td>Scaffold</td>
<td>2.2</td>
<td>2.7</td>
<td>3.2</td>
</tr>
<tr>
<td>TEC-Scaffold</td>
<td>1.8</td>
<td>2.2</td>
<td>2.5</td>
</tr>
</tbody>
</table>

*; p < 0.05

12 wks p/o
Histology of MFC cartilage

Control  | Scaffold  | TEC-Scaffold

OARSI histological score

- Control
- Scaffold
- TEC-Scaffold

**Best score = 0**
**Worst score = 24**
*: p<0.05

Control & Scaffold  ▷ Accelerated OA development
TEC-Scaffold  ▷ Chondroprotection
Macroscopic evaluation of repair meniscus

Control  | Scaffold  | TEC-Scaffold

12 wks p/o

Ratio of meniscal uncovered area (%)

- Control
- Scaffold
- TEC-Scaffold

*; p < 0.05

TEC-Scaffold ▷ Repair and stabilization of hoop structure integrity
Histology of repair meniscus

Control  |  Scaffold  |  TEC-Scaffold

H&E  |  |  

Saf O  |  |  

Dashed arrows indicate the repair tissue.
Bar = 1mm

12 wks p/o

TEC-Scaffold ▷ Repair tissue around the implanted material with positive Saf O staining in inner zone
Discussion & Conclusion

• An electrospun nanofiber scaffold combined with an MSC-based TEC exhibited good potential for repair of meniscal defects, with maintenance of meniscal hoop structure function, as well as evidence for a chondroprotective effect.

• The present technique to repair damaged meniscal hoop structure integrity could contribute to the development of a new meniscal repair technique for a disruption of hoop fibers (e.g., radial tear) with potential for high clinical relevance (5).
References


