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Comparison of synthetic and biologic bilayer implants for the regeneration of vast osteochondral defects - a preliminary study in a sheep model -

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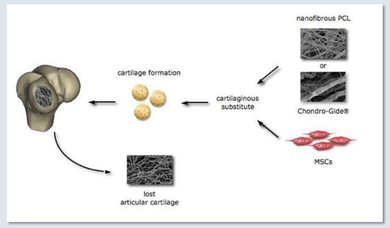
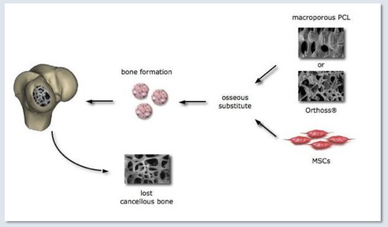
Introduction

Biodegradable bilayer implants were previously shown to promote osteochondral tissue regeneration. When using biomaterials uncertainties prevail with respect to chemical composition, biochemical and biomechanical attributes, and ultrastructure or architecture of the scaffold.

Objective

To assess the ability of a synthetic bilayer implant to be used for the repair of critical sized osteochondral defects in a sheep model. We hypothesized that a biomimetic implant comprised of a macroporous PCL scaffold similar to cancellous bone (▼right figure) with a nanofibrous, electrospun PCL scaffold on top (▼left figure) will create appropriate regenerative conditions for both the chondral and osseous portions of the defect. Combined, they might function as an anatomically shaped implant (synthetic implant: treatment no.2). The combination of Chondro-Gide® and Orthoss® functioned as control (biologic implant: treatment no.1).





Material and Methods

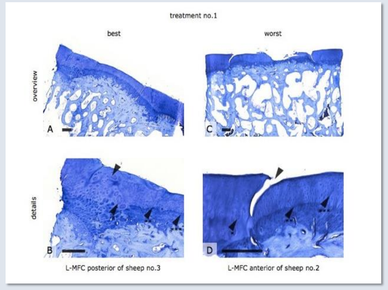
Fresh osteochondral defects (W=6, L=20, D=5 mm) in the weight-bearing area of left medial femoral condyles (L-MFC) were created in 12 skeletally mature female sheep. Animals were randomly assigned to one of the two treatment groups. 19 months post operation, the repair sites were harvested along with their contralateral controls. Biopsies from all L-MFC and untreated surfaces were analyzed for histology (ICRS II score), and sGAG and dsDNA content.

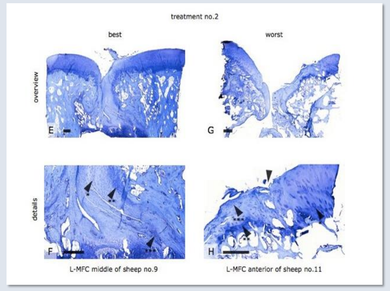
Electromechanical mappings (Arthro-BST™, Biomomentum Inc., Laval, Canada; ◄figure) were performed *ex vivo* on all L-MFC and contralateral condyles (R-MFC).

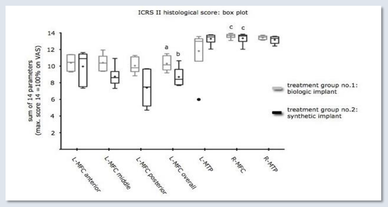
The quantitative parameter (QP) acquired from these mappings is inversely related to electromechanical activity and mechanical stiffness (higher QP = low performance). At each site measured, an Electromechanical Diagnostic Parameter (DP = QP - RefQP (site-specific QP average obtained on the R-MFC)) was calculated also.

Results

Toluidine blue histology of the obtained repair tissue (▼figures A-H) depicted a heterogeneous appearance. Neo-cartilage seemed to be fibrous (F) and partly hyaline-like (D), where cells were oriented in columns (B, D). The surface structure ranged from irregular (G) to smooth (A). Lateral and basal integration was primarily good with tidemark formation in both the best (B) and worst specimens (D, H). Also, subchondral bone of trabecular morphology could be found (A, C). Cell clustering at the boundaries (B, D, H), a uniformly flat calcified layer, tidemark duplication, and occasional vascularization (F) indicated the beginnings of degenerative processes. Specimens were void of bold graft hypertrophy or calcification. All these observations were variable and independent from implant design.







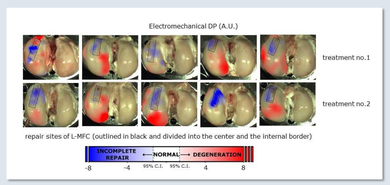
Histological scoring revealed a significantly higher overall L-MFC yield for treatment no.1 (◄figure). For both treatments, L-MFC had a significantly lower score than R-MFC ($p<0.01$ respectively $p<0.0001$).

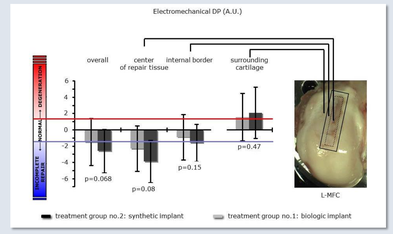
ICRS II histological score ($p<0.02$):
treatment no.1: 10.3 ± 0.38 SE
treatment no.2: 8.7 ± 0.45 SE

Overall, QP values, dsDNA and sGAG contents measured at the repair sites were statistically lower than those obtained from the contralateral surface. This applied for both treatments.

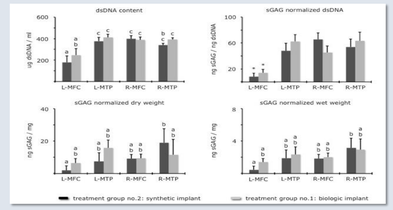
For both treatment groups, Arthro-BST revealed early signs of degeneration of the surrounding cartilage bordering the repair site on the L-MFC (▶figure) but did not reach a significant impact on the degradation of the surrounding cartilage.

DP of surrounding cartilage ($p=0.47$):
treatment no.1: 1.55 ± 2.92 SD (n=922)
treatment no.2: 2.08 ± 3.15 SD (n=963)





Arthro-BST findings were supported by higher dsDNA and sGAG levels for treatment no.1 compared to treatment no.2 (▼figure). This was not significantly different.



Arthro-BST indicated slightly better regeneration for treatment no.1. However, this was not significantly different (◄figure).

overall DP of repair tissue ($p=0.068$):
treatment no.1: -1.50 ± 2.9 SD (n=266)
treatment no.2: -2.62 ± 2.7 SD (n=255)

center DP of repair tissue ($p= 0.084$):
treatment no.1: -2.26 ± 2.8 SD (n=114)
treatment no.2: -3.87 ± 2.6 SD (n=111)

internal border DP of repair tissue ($p=0.15$):
treatment no.1: -0.91 ± 2.8 SD (n=152)
treatment no.2: -1.60 ± 2.3 SD (n=144)

dsDNA ($p>0.05$):
treatment no.1: 247 ± 59 SE mg/ml
treatment no.2: 179 ± 59 SE mg/ml

sGAG / weight ($p>0.05$):
treatment no.1:
^{ww}1.41 ± 0.43 / ^{dw}6.47 ± 2.79 SE ng/mg
treatment no.2:
^{ww}0.46 ± 0.43 / ^{dw}1.95 ± 2.79 SE ng/mg

Conclusion

Both implants allowed for cell infiltration and regeneration of bone *and* cartilage. Nonetheless, repair was incomplete and the quality was more fibrocartilaginous. There were no significant differences observed in the quality of the regeneration between the different treatment groups respectively between the biologic and synthetic bilayer implant design except in some of the categories for histological scoring.

However, we successfully demonstrated the use of Arthro-BST for the non-destructive and quantitative assessment of cartilage repair techniques. The results from those measurements were comparable to traditional measures preformed in this study.

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Wissen schafft Gesundheit

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