Fascial Tissue Reconstruction Using Acellular Collagen Matrix

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Statement of Purpose: Various synthetic and naturally derived materials have been proposed as possible materials for fascial reconstruction. An ideal biomaterial should be biocompatible, non-immunogenic, be able to promote formation of new tissue by cellular in-growth, and be able to withstand tensile forces until the newly developed tissue maintains structural integrity. Biocompatibility is a critical factor in assessing a biomaterial because the formation of a new tissue depends primarily on the interactions of the biomaterial with the host infiltrating cells and surrounding tissues. Acellular collagen matrices have been used experimentally and clinically for several applications, including urethra and bladder reconstruction(1,2). We investigated the feasibility of using a naturally derived, non-immunogenic, biodegradable, collagen-based matrix derived from porcine bladders as an off-the-shelf biomaterial for fascial tissue repair in 3 different tissue systems.

Methods: To demonstrate the biocompatibility of the biomaterial, a direct contact cell viability assay, a direct contact mitochondrial metabolic activity assay, and a quantification of apoptosis were performed according to the established standards(3). Cells on plates not exposed to the biomaterial served as a negative control and cells in contact with latex fragments as a positive control. The material-cell contact was maintained for 3 days at $37^{O}C$ and 5% CO_2.
The acellular collagen matrices were used as a sling material for the treatment of incontinence, for the treatment of abdominal hernias and penile tunica reconstruction in 24 rabbits. The animals were evaluated at various time points and sacrificed 1, 2 and 3 months after implantation.
Immediately after euthanasia, the implant site was inspected. Parameters assessed for gross examination included the integrity, size and integration of the biomaterial into surrounding connective tissue, fibrosis, infection and inflammatory response.
The retrieved tissue specimens were fixed in 10% neutral formalin. Five micron thick sections were obtained from the paraffin embedded blocks followed by Hematoxilin and Eosin (H&E), a staining method widely accepted for the assessment of local inflammatory response. Elastin and Collagen stains were performed. For ultrastructural analysis, scanning electron microscopy was performed. Retrieved implants obtained at each time point were fixed, critical point dried and sputtered using a gold platinum coating. The samples were analyzed using a scanning electron microscope at 500x, 1500x and 5000x magnification.
Rectangular tissue strips (16 mm x 6 mm), obtained from the abdominal hernia repair were used for mechanical testing. The tendenous portion of the native external abdominal muscle served as a normal control.
The porosity of the biomaterial was measured by liquid displacement and flow method.

Results / Discussion: The direct cytotoxicity and mitochondrial metabolic activity assays showed that the acellular matrix did not induce significant changes in cell viability when compared with the controls. The apoptotic activity of the fibroblasts cultured in direct contact with the collagen matrix was minimal. As expected, Latex showed a significant increase in apoptotic activity.
The liquid displacement method showed a porosity of 76% and 1.6 $ml/min/cm^2$ in the flow method.
All 24 Animals survived without any noticeable side effects. The acellular matrices remained intact at their respective implantation sites and demonstrated maintenance of fascial tissue function. At the time of retrieval there was no evidence of inflammation or infection and minimal adhesion was noted.
The biomechanical properties of the collagen matrices were similar to the normal controls. There was no significant difference in the maximum tensile stress (MPa) noted between the 0, 1, 2 and 3 month time points for both biomaterials; however a trend towards improvement of strength over time could be observed.
Histologically, the matrix structure was intact, demonstrating the longitudinal collagen bundles in both groups at all 3 time points. The amount of collagen did not change over the study period. There was only a minimal inflammatory response consisting of lymphocytes and eosinophils, which gradually decreased over time. The cell density decreased over time and a shift from dominance of lymphocytes to dominance of fibroblasts was observed.

Conclusions: These results show that acellular collagen matrix derived from porcine bladders is biocompatible, durable and safe for use in vivo. This matrix may be used as an off-the-shelf biomaterial for sling operations, for penile reconstruction and for the treatment of abdominal hernias.

References:

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