Potential utility of woven flax fiber meshes in surgical repair of incisional hernias

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Statement of the Purpose: Implantable mesh structures have become indispensable in surgery, particularly for the repair of incisional hernias in the abdominal wall. These techniques started with polypropylene woven meshes, but there is now a clear trend toward "biological" animal-derived meshes (e.g. prepared from porcine skin).[1] It is, however, still unclear whether these biological meshes really provide meaningful advantages over their synthetic counterparts.[1] Here, we explore the idea of using implantable woven meshes, which are manufactured from a plant-derived fiber. Flax (Linum usitatissimum) was chosen because of its excellent physical-mechanical properties, its non-biodegradability, and in view of existing know-how on weaving/knitting of flax (linen).[2]

Materials and Methods: Starting with a bleached flax thread, a prototype mesh was industrially woven in a design similar to the Polypropylene Prolene™ (Ethicon, Livingston, United Kingdom). Mesh was used "as received" or treated for 48hrs in Soxhlet with 5% acetic acid for the first 24hrs, and 75% ethanol for the last 24hrs. In vivo biocompatibility was evaluated by inserting subcutaneously sterile meshes of 3×1cm on the back of male rats. After 7 days of follow-up, rats were euthanized and tissues were stained with hematoxylin and eosin (H&E) using standard histological techniques. In vivo results were explained using a Limulus Amebocyte Lysate (LAL) test from Lonza to dose the amount of endotoxins present in 1×1cm meshes. Sterile meshes were incubated overnight at 37°C in 1mL endotoxin-free ddH_2O. Amount of endotoxins present in the extracted water was determined following manufacturer's instructions. Results obtained with LAL test were corroborated by XPS analysis on meshes before and after Soxhlet treatment.

Results: Histopathology revealed that the untreated flax mesh provokes severe inflammation, pus formation and necrosis in its vicinity. The Soxhlet-treated mesh also caused inflammation and cell death, but on a much smaller scale. Inflammation and necrosis were encountered not so much around the mesh, but mostly at sites where woven threads cross, or inside the multi-fiber threads, when cells had penetrated in between more or less loose filaments. LAL test showed that the improvement seen after soxhlet treatment is mostly due to the fact that ethanol removes endotoxins: extracted water from 1×1cm untreated mesh contained as much as 7.0 Endotoxin Unit (EU) in 1mL ddH_2O, whereas after soxhlet treatment only 0.5EU were detected. XPS analysis also demonstrated that soxhlet treatment resulted in a huge decrease in C-C bonds ratio (from

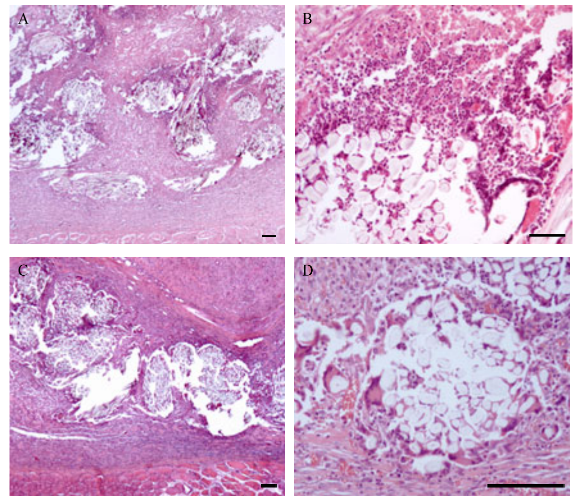

Figure 1. H&E staining of explanted materials, black bars represent 500 µm. Picture A shows the untreated mesh after 7 days, with thick fibrous capsule formation and massive inflammation around mesh fibers. Detail picture (B) shows inflammation with necrosis. In picture C the Soxhlet treated mesh with detail (D) showing less inflammation and foreign body reaction.

71% to 25%) whereas ratio of C-O and O-C-O bonds increased. This decrease of C-C bonds can be related to the extraction of endotoxins, which contain long aliphatic side chains, and so to the purification of flax fibers.

Conclusion: The idea to use plant-derived fibers in the manufacture of surgical meshes is probably feasible. The present data, derived from woven flax meshes, show that an adequate level of biocompatibility can be achieved provided that endotoxins be removed effectively. Much further work is necessary, especially to optimize technical parameters, such as weaving pattern and thread thickness. Combination of the new data with existing knowledge on woven flax structures reveals that it will be possible to achieve desired combinations of strength, light-weight, open mesh structure and biocompatibility in vivo. This approach may provide a route to new "biological" meshes for use in surgery, in this is likely to be particularly relevant for repair of incisional hernias in the abdominal wall.

References:

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