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DOES POLYPROPYLENE MESH ANISOTROPY PERSIST AFTER IMPLANTATION?

Hypothesis / aims of study:
Anisotropy is a physiologic feature of most biological tissues. A different stress response to changing stretch directions is there to meet the anatomical and functional needs. According to the scanty available data, the *vagina* also has anisotropic properties, and its musculature provides most support in the longitudinal direction [1]. Though the exact relation between function and structure remains to be elucidated, more recent pelvic floor reconstruction materials are designed such that they meet the properties of the structure they are supposed to repair. Ultrapro (Johnson & Johnson, Norderstedt, Germany) is a polypropylene based structure wrap-knitted with resorbable polyglecaprone fibers and a pore size of 3.8 mm² (Amid type I; density after resorption: 32.0 g/m²). The material has a predefined fiber orientation that provides the implant anisotropic properties. The blue marking lines on the mesh are parallel to the fiber direction; hence define the stiffest axis (Fig 1). Conversely, the direction perpendicular to these blue lines is more compliant. We investigated in a large animal experimental model for primary incisional repair whether and how much anisotropy persists as resorption of polyglecaprone and in growth of host tissue proceeds over time.

Study design, materials and methods:
First, tensiometry was done on Ultrapro implants 2.0 by 4.0cm in its most stiff (UPS; n=6) and most compliant direction (UPE; n=6) ["dry tests"]. All materials were tested with a 200N loadcell on a 500N Zwicki uni-axial tensiometer (Zwick GmbH & Co. KG, Ulm, Germany). After the preconditioning phase (10 cycles at 20% elongation), the samples were tested until failure (60 mm/min). The *maximal stress* (N/mm²) and *the strain at maximal stress* (%) were recorded. An area of low and high stiffness can be discriminated, referred to as the *comfort zone* and *stress zone* [2]. The *stiffness* (N/cm²) in both zones was determined using TestXpert II software (Zwick) as the best-fit linear regression between two manually chosen references in each zone of the recorded stress/strain curves. The transition between both zones can be described by the strain corresponding with the *intersection* of both regression lines (%), which is a measure of the length of the comfort zone. We then used 12 New-Zealand white rabbits which underwent creation of two full thickness 2cm abdominal wall incisions, sutured primarily with polyglecaprone 4/0 (Monocryl, Johnson & Johnson). Rabbits were then randomly assigned to covering of both defects with the materials (5.0 by 4.0cm) in one specific orientation, so that either the most compliant (UPE) or the stiffest (UPS) direction of the implant was parallel to the body axis. This provided 6 rabbits in each group, two of them sacrificed after 30, 60 and 120 d each. At sacrifice an area including the material and underlying host tissue, was harvested. This explant was further reduced to two pieces of 4.0 cm (longitudinal) by 2.0 cm (transversal) and used for immediate measurement and biomechanical testing as above, again providing test results in either the most compliant or stiffest orientation of the implant in dry conditions. Abdominal wall explants of an additional three unoperated animals served as controls.

Results
Prior to implantation (dry measurements), the stiffness in both the comfort and stress zone was significantly higher in UPS implants. Conversely, for UPE implants, the intersection shifted to higher strains as well as did the strain at maximal stress. The maximal stress of UPE was significantly reduced compared to UPS implants. *After implantation* the stiffness in the comfort zone for UPE samples was less than for UPS specimens, both at 30 and 120 days. At 60 days an inversion occurred. In the stress zone, UPE explants were more compliant at 30 days but not at other time points (Fig 2). The transition between the comfort and stress zone was at higher strains for the UPE samples at 30 and 120 days with again an inversion at 60 days. After 120 days the UPE samples resisted higher stress than UPS and ruptured at higher strains.

Interpretation of results:
In dry conditions, Ultrapro implants are indeed anisotropic. When tested along the blue marking lines, the implants are stiffer in both the comfort and stress zone. In that direction the fibers rather than the implant structure are being stretched, thus resulting in high stresses and low strains. When tested perpendicular to the blue lines, the structure of the mesh is deformed, resisting lower stress but higher strains. In the comfort zone, the anisotropic properties of Ultrapro implants remain for up to 120 d after implantation. In the stress zone, anisotropy is conserved at 30 d. At 60 d however, UPE became as stiff as UPS samples. Further histology may elucidate why this is so. Apart from that, following host tissue in growth, both UPS and UPE explants remain stiffer than the native tissue. The transition between the physiological strain range and the stress zone remains comparable to that measured in dry conditions, suggesting that the mesh or fiber structure remains responsible for the behaviour of the functional entity of mesh and ingrown tissue.

Concluding message:
Ultrapro is an anisotropic material prior to implantation. These properties change to some extent after integration into the host. In the physiologic stress range (comfort zone) anisotropy remains conserved, whereas in the stress zone it is not. However, explants stiffness is still not comparable to that of native tissue. Of note is that the axis of highest stiffness of the vagina coincides with the stiffest axis of Ultrapro, the way it is now clinically implanted during sacropexy. The same product, marketed as Prolift Plus M, however is implanted vaginally at a 90° angle to this. Provided that anisotropy would also be conserved

clinically, the direction of implantation of such implants would matter in terms of vaginal compliance. It remains at present uncertain whether this has any functional relevance.

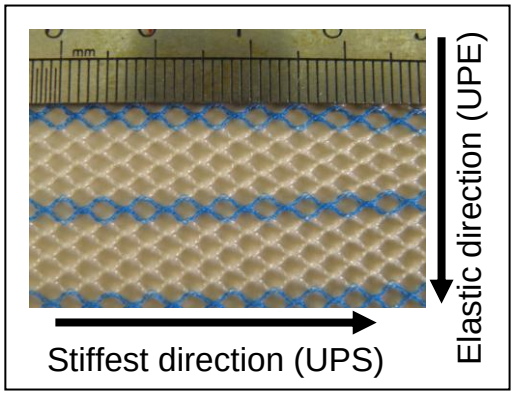

Figure 1: Anisotropy. Detail of an Ultrapro mesh. The arrows indicate the elasticity difference according to the direction of forces.

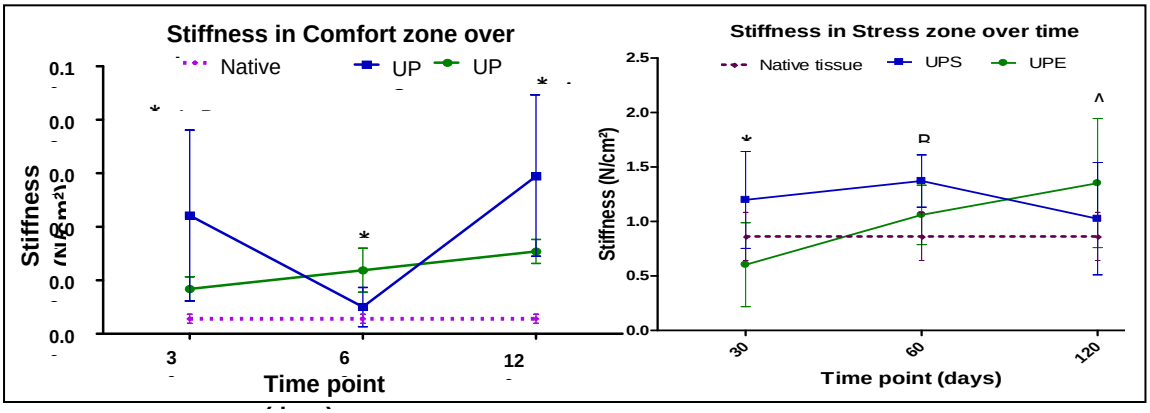

Figure 2: Stiffness in comfort and stress zone over time for UPE and UPS samples compared to native tissue (mean +/- S.E.M.). * indicates significant difference based on Mann Whitney U test between UPE and UPS ($P<0.05$) [A] indicates significant difference based on Mann Whitney U test between UPE and native control ($P<0.05$) and [B] between UPS and native control.

References

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Is this a clinical trial?	**No**
What were the subjects in the study?	**ANIMAL**
Were guidelines for care and use of laboratory animals followed or ethical committee approval obtained?	**Yes**
Name of ethics committee	**Ethics Committee for Animal Experimentation of the Faculty of Medicine of the K.U.Leuven**