State of the knowledge in "mesh shrinkage" – What do we know?

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Introduction

"Shrinking meshes" are a topic of discussion and concern among hernia surgeons. It is believed that mesh shrinkage may lead to patients' discomfort, chronic pain or hernia recurrence. In order to define the product requirements of a next generation mesh in terms of less shrinkage, a literature research was performed. Goal of this research was to find out what is currently known about mesh shrinkage and which factors (on the patients' side as well as on the mesh side) influence mesh shrinkage.
Following is a summary of different factors that are discussed to be related to mesh shrinkage in the literature (see list).

Factors related to mesh shrinkage

1. **Mesh material/Mesh weight/Mesh shape**

The degree of mesh shrinkage is not only dependent on the material that is used but also on factors like weight, surface area, pore size and fiber architecture (24). Since "pore size" seems to be one of the most important factors regarding mesh shrinkage an individual section (section 2) is used to address this issue.
In general, it is very challenging to compare different mesh materials regarding their tendency to shrink, because of the diverse models that have been used and the variable results that are shown. In spite of these discrepancies there a some general conclusions drawn out of the different shrinkage studies:

The reduction of the biomaterial (for example Polypropylene) content reduces both the inflammatory reaction and the mesh shrinkage. In most studies lightweight meshes show less shrinkage than heavyweight meshes (1; 5; 14), while other studies reveal no differences (16). Regarding the material itself Polypropylene (PP) meshes show less tendency to shrink than GoreTex, while Polyester shows a slightly lower amount of shrinkage than PP (1; 13). The percentage values differ a lot in the different models used, they range between 15% and 65% of original mesh size for a heavyweight PP mesh in a dog model (5) and only 5% to 11% for a lightweight PP mesh in a rat and a pig model respectively (2; 14). The Ultrapro mesh shows less contraction compared to a PP-mesh of the same weight, at least in a long-term observation. This is believed to be due to the absorbable part of the mesh that leads to a diminished Foreign Body Reaction (6; 16; see also section 4).
In a study performed to evaluate different meshes in intraperitoneal placement, DualMesh (Gore) and Tutomesh (Tutogen) showed significantly more shrinkage than other products. The increased shrinkage of DualMesh was confirmed in more studies (2; 31)

In addition to material and weight, the mesh shape also has an impact on mesh shrinkage. After implantation and depending on their looseness, mesh plugs shrink up to 75%. As a result, the anchoring sutures of the plug may pull through the margin of the defect, leading to a recurrence. In this case the relationship between surface and volume is important. A flat mesh has been shown

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to lose approximately 20% of its size due to tissue maturation. A plug will lose 70% of its volume if it loses 20% of its surface area (11; 28).

2. Pore size

The tissue incorporation of a mesh prosthesis is proportional to its pore size, since macroporous structures are required for the entrance of macrophages, fibroblasts, blood vessels and collagen fibers. Larger pores allow for faster ingrowth into the mesh, which results in less contraction. On the other hand, the small pore mesh incorporates entirely in perifilamentary granulomas and scar tissue, which bridge the whole pore diameter. This so called "fibrotic bridging" is a phenomenon that is believed to be closely related to mesh shrinkage and is usually observed in all mesh modifications with pore sizes of less than 1mm. Biomaterials containing pore spaces of less than 75 μm are more prone to be encapsulated rather than infiltrated by the host tissue (1; 6; 11; 16; 19; 20).

3. Mesh size

Since the mesh is contracted by the normal wound healing process, sufficient long term hernia repairs can only be performed with large meshes overlapping the defect by a minimum of at least 5 cm at each side (6; 15). A review of large series of traditional preperitoneal herniorrhaphy displays a disparity in the recurrence rate for those surgeons using a small prosthesis and those using a large prosthesis. In the case of a too small prosthesis minimal migration or shrinkage of the mesh from fibroblast ingrowth may result in uncovering of the hernia defect, leading to a higher rate of recurrences (27).

4. Intensity of FBR (foreign body reaction)

The quantity and quality of the local inflammatory reaction depend directly on the type of mesh that is used. All experimental and clinical studies indicate a typical FBR at the interface of all mesh modifications on the market today (6; 32).
The formation of connective tissue correlates with the amount of inflammation. In explanted meshes, the quantity of inflammatory cells (macrophages and polymorphonuclear leucocytes) is directly correlated with the number of fibroblasts. The amount of fat tissue is inversely proportional to the amount of connective tissue and decreases over time (10; 32).
Polyester and PP induce a rapid and acute inflammatory response with a limited fibroblastic response and a strong scar formation. However, the FBR does not only depend on the polymer, but also on the surface area of the mesh. The leightweight and large pore size meshes have less surface area than the heavyweight mesh group, consequently the FBR in the leightweight mesh group is significantly reduced. Heavyweight meshes with small pores induce an intense chronic FBR with intensified bridging scar formation (6; 19; 32).
An increased FBR with a persisting inflammation and subsequent formation of a rigid scar plate appears to be primarily responsible for the shrinkage of PP meshes in vivo. Decreasing the biomaterial content of these meshes reduces both inflammatory response and shrinkage (1; 5; 24).
All these hints may lead to the conclusion that the perfect mesh does not induce any FBR. However, it must be considered that an immediate postoperative inflammatory reaction is required for adequate mesh incorporation into the tissue because mediators involved in this process provide the elements necessary for the regulation of local defense, scar formation and wound healing (1).

5. Implantation site

The topic of variations in mesh shrinkage due to different implantation areas has not been addressed very often, although it must be assumed that the position of the mesh (e.g. intraperitoneal, extraperitoneal or subcutaneous) will have a varying impact on the tissue reaction, shrinkage or both (13). Most studies abandon the fact that explanted meshes analyzed in terms of shrinkage or inflammatory reaction arise from different implantation sites. Therefore, the influence of this factor cannot be considered and may even tamper the results. (10; 12; 15). In one of the few studies dealing with this topic macroporous meshes were implanted in two different sites of a rat model. Meshes implanted on the abdominal aponeurotic layer showed a better early tissue incorporation and increased tensile strength, reflecting higher anchorage to the abdominal wall. On the peritoneal surface, the mesh showed a higher tendency of folding. Possible explanation: When abdominal movements occur, associated mechanical tensions are created. These tensions must be absorbed by the surrounding tissues. Absorption in the abdominal aponeurotic layer seems to be distributed between the mesh and the receptor healing tissue in a balanced manner. On the peritoneal surface, however, the mesh appears to be less well integrated into the scar tissue. Thus tension would be mainly absorbed by the receptor tissue, leaving the mesh more susceptible to folding (8).

6. Speed/extent of tissue ingrowth

Mesh contraction is also suggested to occur as a result of inadequate tissue ingrowth into the mesh. A strong integration of the mesh into the tissue helps to prevent this phenomenon, which is evidenced by a significant correlation between tissue ingrowth force and mesh size. Therefore, a biomaterial that induces a swift and adequate tissue ingrowth into the mesh should be used to help reduce recurrences and decrease shrinkage and migration. It is believed, that once the acute phase of the inflammatory process is concluded and the mesh is well integrated into the tissue, there should be no further contraction (1; 5; 32).
The shrinkage of a PP-mesh in humans has been investigated with an X-ray technique. Mesh shrinkage was evaluated at different time points and the reduction of the calculated area was 12% at one month, 24% at 3 months, 29% at 6 month and 34% at 12 month. This leads to the conclusion that the main part of mesh shrinkage occurs during the first three months (30).

7. Fixation means

Proper fixation acts to prevent early displacement, folding or bulging of the prosthesis into the defect in the early postoperative period, before cellular infiltration and collagen deposition. The shrinking process probably is helped forward by inadequate fixation of the mesh in the early phases of tissue integration (13; 27).
On the other hand, surgeons are concerned about a failure of the initial fixation due to mesh shrinkage. Actually there are a few studies showing contracted meshes that had detached from the fixation points. In these cases however it is uncertain if the detachment of the mesh is the cause or the effect of the shrinkage. It is supposable that the mesh detaches right after the procedure due to insufficient fixation. Shrinkage may then occur before the mesh has time to integrate into the tissue (1).

8. Edge quality of implant

The edges of the implant should be smooth and unraveling has to be prevented, because this may lead to an excessive inflammatory reaction. The polypropylene meshes were initially woven but were then changed to a warp-knitted construction to prevent unraveling of the cut edges of the mesh (16).

9. Physiological wound contraction

A phenomenon that occurs simultaneously with collagen synthesis is wound contraction. Among other reasons, shrinkage seems to be a consequence of the physiological wound contraction, initially by dehydration of soft tissue and later by maturation and crosslinking of the collagen fibers. So the mesh itself does not shrink but is contracted by the surrounding tissue. Nevertheless, since the mesh affects the intensity of both inflammatory reaction and wound contraction it is indirectly related to the amount of shrinkage (4; 5).
Like the FBR (see section 4) wound contraction cannot be completely prevented since it is needed to achieve a stable scar tissue (7).

10. Individual/patient related factors

Some studies show significant differences in mesh contraction between identical mesh types and identical implantation sites. In a study dealing with the response of blood monocytes from different human donors to mesh biomaterials the individual was identified as an independent factor for the inflammatory response to biomaterials. Moreover, high and low responders could be identified. The development of an excessively contracted scar in some individuals is thought to be the reason of myofibroblast apoptotic cell death. The origin of these high and low responders may be genetic but this remains to be determined (1; 25; 26).
The patient related factors should be kept in mind when the shrinkage of explanted meshes from humans is investigated. In these studies, most likely only the "high responders" are considered since meshes that do not cause any complications are not removed. There is evidence that meshes observed incidentally in a second surgery don't show any changes at all, even years after the initial hernia surgery (Schimmelpenning, personal communication).

11. Additional factors

Additional factors that are discussed in terms of mesh shrinkage are contacts of the mesh with different fluid media such as blood, saline solution and water. In general, the interactions of the surrounding with the mesh material seem to be more complex than assumed previously (13; 22).

Conclusion – the "ideal mesh"

Taking all these abovementioned facts into consideration, the ideal mesh could appear as follows:

- lightweight material (partly absorbable)
- pore size >1mm
- mesh size large enough to cover the defect sufficiently
- mild but not excessive FBR and wound contraction
- swift and adequate tissue ingrowth warranted
- proper fixation to prevent early displacement
- smooth mesh edges

In addition to these "mesh based" factors it is advisable to gain more information about patient related factors and the influence of different implantation sites on mesh shrinkage. This may lead to individually designed meshes in the future.

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