A Narrative Review on Polypropylene Mesh Complications in Inguinal Hernia Repair - is Titanized Mesh an Option?

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Citation: Holzheimer RG (2022) A Narrative Review on Polypropylene Mesh Complications in Inguinal Hernia Repair - is Titanized Mesh an Option?. J Surg 7: 1549. DOI: 10.29011/2575-9760.001549

Received Date: 08 August, 2022; Accepted Date: 16 August, 2022; Published Date: 22 August, 2022

Abstract

Introduction: Since the introduction of mesh in Inguinal Hernia Repair (IHR) the recurrence rate was lowered. Instead, postoperative pain which may be related to mesh side effects e.g. fibrosis, foreign body reaction, erosion and migration, and infection, has been recognized as the relevant outcome factor. The long-term effects of mesh and composite mesh need to be analyzed.

Methods: Pubmed, google scholar search using the search terms: polypropylene mesh, titanized mesh, TiMesh®; about polypropylene mesh the following terms: adhesion, erosion, infection, shrinkage, migration, seroma, degradation, pain; biocompatibility, foreign body reaction. Also, a bibliography of relevant articles and product-related information was searched.

Results: Mesh properties are determined by tensile strength, pore size, weight, reactivity and biocompatibility, elasticity, constitution, and shrinkage. PolyPropylene Mesh (PP) is associated with actual and long-term complications more than expected. These complications are associated with mesh structure-lightweight meshes showed fewer risks for complication as infection, pain, mesh migration, foreign body response, erosion, adhesion, shrinkage, pain, seroma, and recurrence. TiMesh® showed an advantage in in-vitro and animal studies which were supported by clinical studies. There is a shorter convalescence, and lesser foreign material sensitivity with comparable results in complications (Chronic pain, infection, recurrence).

Conclusion: Polypropylene mesh has been successful in inguinal hernia repair for decades. However, in recent years complications of PP became evident in scientific reports and the public. Complications seem to be related to the material and structure of the mesh but also to the surgeon’s expertise and patient’s characteristics. It became evident that more complications appear long-term. The true rate of complications could be higher. There are a few clinical reports on titanium-coated mesh (TiMesh) in TAPP and TEP inguinal hernia repair. Experience with TiMesh in laparoscopic procedures long-term and open IHR are missing. Especially about the long-term effects of coating PP with titanium we need to have a better understanding of the interaction of soft tissue and mesh. There are promising results of pure titanium mesh for inguinal hernia repair which need to be confirmed in further controlled clinical studies.
Introduction

The use of polypropylene mesh for hernia repair has been published by Usher for the first time [1]. The EU trialist collaboration found that mesh is superior to suture technique in inguinal hernia repair about pain and recurrence [2]. However, mesh and fibrosis turned out to be responsible for pain and other disturbances. Contrary to the manufacturer’s disclosures, synthetic materials polypropylene mesh is not without disadvantages and may cause complications [3]. In a report by Anna Collinson and Jessica, Fürst BBC reported on 26th September 2018 that hernia mesh complications affect more than 100,000 patients (complication rate 12-30%) during the last six years before the report in England. Up to 170,000 people who had hernia mesh implants in England over six years could face complications due to BBC’s Victoria Derbyshire program [4]. According to this program, many types of hernia mesh implants are being used with little or no clinical evidence [5]. The lightweight mesh may be associated with less chronic pain but an increase in inguinal hernia recurrence [6]. The selection of the mesh depends on the patient’s characteristics (age, underlying disease, defect size, preoperative pain). The surgeon should know about mesh properties that are relevant for the success of implantation and for avoiding complications related to mesh: tensile strength, pore size, weight, reactivity and biocompatibility, elasticity, constitution (monofilament, multifilament, patches), and shrinkage. Most complications in inguinal hernia repair with PP mesh are related to the mesh properties. Complications of meshes are infection, adhesion, erosion, shrinkage; migration; seroma, degradation, pain, and recurrence. There is a search for mesh that reduces the risk of complication. Titanized mesh demonstrated improvement in patient reactions to the implanted mesh.

Materials and Methods

Pubmed, google scholar search using the search terms: polypropylene mesh, titanized mesh, TiMesh®; about polypropylene mesh the following terms: adhesion, erosion, infection, shrinkage, migration, seroma, degradation, pain; biocompatibility, foreign body reaction. Also bibliography of relevant articles and product-related information was searched.

Mesh Properties

Mesh properties are determined by tensile strength, pore size, weight, reactivity and biocompatibility, elasticity, constitution, and shrinkage [7].

Tensile Strength

Coughing and jumping generate maximum intra-abdominal pressure (170 mmHg; 32 N/cm), which makes it obvious that the tensile strength of meshes (100 N/cm) may not be advantageous [8].
Elasticity

HWM (elasticity 4-16%) when compared to LWM (elasticity of 20-35%) may restrict the distension of the abdominal wall [26]. The mismatch of mechanical properties between soft tissue and mesh, causing a permanent PP mesh deformation, may increase the risk of mesh failure [27].

Constitution

Constitution is formed by multifilament and monofilament fibers with multifilament fibers increasing the risk of infection [28].

Shrinkage

PP mesh may cause an inflammatory response, foreign body reaction, and scar tissue, which may be responsible for shrinkage [29]. Prosthetic meshes are not inert as claimed to be and can expand as well as shrink [30]. Shrinkage depends on both mesh properties-small pores producing scar tissue - and the anchoring device [31]. Mesh characteristics should be considered when choosing the mesh for IHR [32].

Mesh Complications

Complications of Anterior Inguinal Hernia Repair

In a meta-analysis, there was no difference between Prolene Hernia System® (PHS) and Lichtenstein IHR for recurrence, chronic pain, operating time, composite complication, and surgical reintervention [33]. Meta-analysis showed that Mesh-Plug Repair (MPR) requires a shorter operation time than Lichtenstein herniorrhaphy, and there is no significant difference in postoperative complications or recurrence rate [34]. This meta-analysis indicates that MPR mesh plug repair and PHS® seem comparable to LR Lichtenstein repair in terms of recurrence, chronic pain, time to return to work, inguinal paresthesia, testicular and scrotal problems, hematoma, seroma and wound infection. MPR and PHS® seem comparable in terms of recurrence, chronic pain, and wound infection [35].

Complications of Laparoscopic Inguinal Hernia Repair

A meta-analysis comparing Lichtenstein and TAPP indicates that the complication rate and outcome of both procedures are comparable. TAPP operation demonstrated only one advantage over Lichtenstein operation with significantly less chronic inguinal pain postoperatively [36]. TAPP was associated with a lower seroma rate, and TEP was associated with a lower edema rate according to a meta-analysis [37]. There was less early pain and fewer analgesics after TEP repair, compared to Lichtenstein repair with similar infection rates in this Randomized Controlled Trial (RCT) [38].

Mesh and Vessels

Mesh-induced inflammation and fibrosis may influence blood flow in arteries and veins [39]. Mesh fibrosis may not affect testicular flow [40]. However, dysejaculation and pain-related impairment of activity may be a complication of laparoscopic inguinal herniorrhaphy [41]. Tailored neurectomy, funicular release, and or mesh removal may be helpful [42]. In a recent systematic review, it has been stated that hernia repair with mesh-open or laparoscopic-does not affect male fertility [43].

Infection

Filament type and pore size are decisive factors for infection which may become apparent years after implantation. Meshes with monofilament and large pores reduce the risk of infection [44]. Polytetrafluoroethylene polymer, multifilament meshes, increased filament diameter, increased mesh weight, and smaller pore size increase bacterial adherence as does the addition of Prolene suture material [45]. Risk factors for mesh infection are obesity, smoking, and diabetes [46]. There are reports of late-onset deep graft infection. With the more widespread use of mesh materials, this complication may become increasingly evident [47]. Peripheral blood inflammation markers predict surgical site infection after mesh inguinal hernia repair [48]. There is an increased risk of infection due to the larger size of mesh used in laparoscopic repair [49]. The incidence of mesh infection maybe 4.97%. Duration of surgery and mesh contamination is relevant to the incidence of mesh infection [50]. The risk of mesh infection following laparo-endoscopic IHR may persist for more than 5 years and probably as long as the mesh remains in the body [51]. In microbial adhesion tests (High-density Polypropylene Monofilament Mesh (PMM); Low-density PMM; prostheses composed of low-density polypropylene and a non-porous hydrophilic film (composite prostheses) depending on the type of bacteria collagen-coated hydrophilic prostheses with a large surface increased bacterial adherence [52]. Chronic mesh infection may be complicated by an enterocutaneous fistula [53]. Late-onset ileocutaneous fistula should be considered in case of inflammation and absces formation even eight years after hernia repair [54]. Delayed mesh infection may present 11 years after inguinal hernia mesh plug repair [55]. The infected mesh may be removed when conservative treatment fails open or laparoscopically [56,57].

Adhesion

All meshes induce adhesion. Absorption is reduced by ischemia, inflammation, and the foreign body. Pore size, filament structure, and the surface of the mesh structure are decisive in how much adhesion is produced when the mesh is placed in the vicinity of the bowel. Microporous structure at the side of the bowel and additional surface [58] in composite meshes provide a temporary
barrier against adhesion. However, the absorbable coatings may be degraded in the short term [59].

**Erosion**

Mesh erosion into intra-abdominal organs [60-62] is a serious long-term complication, which may be clinically apparent with unspecific symptoms. Mesh migration, adhesion, and formation of granulation tissue are relevant mechanisms [63] that may lead to enterocutaneous fistula [64]. Treatment of mesh erosion may be possible by a laparoscopic approach [65]. It is important to completely close the peritoneum when placing the mesh [66]. 23% of patients in a case series experienced early intestinal erosions occurring during the first 6 postoperative months while the remaining 67% occurred after 6 months. Patients presented most commonly with symptoms of acute obstruction followed by a palpable inguinal mass. The late presentation group after six months exhibited significantly more cases of mesh erosion when compared to the early presentation group. Early cases were more often associated with mesh fixation material erosion and symptoms of acute intestinal obstruction. An open primary procedure was more common in late cases while the early presentation was linked to laparoscopic procedures. Bowel resection was more frequently required in late cases [67].

**Migration**

IHR turned out to be the index operation in 62.9% (51.8% open repair, 42.9% laparoscopic, 1.8% robotic) of reports on mesh migration including polypropylene mesh and composite mesh affecting often multiple organs [68]. Mesh migration-induced colon inflammation or perforation can occur several months to 12 years following hernioplasty [69]. Mesh migration after laparoscopic inguinal hernia repair is more common after transabdominal preperitoneal repair as compared to Total Extraperitoneal (TEP) repair [70]. Mesh may be removed laparoscopically [71] Mesh migration may cause colocutaneous fistula [72], large scrotal hernia [73], mechanical bowel obstruction [74], small bowel volvulus [75], and mesh plug migration into the bladder [76]. Recommendations to avoid or reduce the risk of this complication: careful preperitoneal dissection to avoid/repair tears of the peritoneum; secure placement of mesh/mesh plug [77].

**Mesh Fixation**

A self-gripping mesh for hernia repair may result in less pain in the early postoperative phase but chronic post herniorrhaphy pain is not affected. Recurrence rates may be a potential disadvantage [78]. Mesh fixation with glue compared with sutures in Lichtenstein repair inguinal hernia is faster and less painful, without an increase in terms of recurrence rates in the long term [79] The self-gripping mesh and sutured mesh have a similar incidence of chronic postoperative inguinal pain, recurrence, and foreign body sensation. The main advantage of the self-gripping mesh is the consistently significantly reduced operation time [80]. Early and late recurrence was comparable between glue and suture fixation in open Lichtenstein IHR patients. Glue fixation had a shorter operating time and lower hematoma formation than suture fixation. Chronic pain and seroma formation were comparable [81]. In PP HWM or LWM, neither mechanical nor glue fixation improves the outcome of laparoscopic IHR. In HWM non fixation and LWM, fibrin glue fixation has been recommended [82]. There remains no superiority in terms of mesh fixation; the choice of fixation remains with the surgeon’s expertise and the patient’s preference [83].

**Recurrence**

The rate of recurrence has been reduced by the use of mesh. However, there are reports of recurrence after mesh inguinal hernia repair (13% of all herniorrhaphies worldwide). In most instances, the cause of recurrence is not the type of mesh, but inadequate fixation and underestimation of mesh shrinkage as the recurrent hernia occurs at the edge of the meshes (O’Dwyer). Patient risk factors are higher BMI, smoking, diabetes, and postoperative surgical site infections. Surgical risk factors are surgeon’s experience, mesh with sufficient overlap, and surgical technique. Type of mesh and fixation of mesh were not significant factors for recurrence [84,85].

**Pain**

Although the tension-free technique of mesh inguinal hernia has been associated with less postoperative pain, Foreign Body Reaction (FBR) including nerve fibers and fascicles, neuromas at the interface of mesh and soft tissue suggest the destruction of nerves may be responsible for pain in IHR. Mesh with small pores induce a greater FBR leading to higher rates of chronic pain [86]. Despite the popularity and outcome of mesh repair persistent postoperative pain still occurs and may become more evident with the interest in laparoscopic hernia repair [87]. Removal of a meshoma must be considered as success rates are optimized following these measures [88]. The choice of the mesh or fixation method did not affect the overall long-term outcome, pain, or recurrence of the hernia. Less penetrating fixation (Glue or self-gripping mesh) is a safe option for the fixation of mesh in Lichtenstein hernia repair [89]. Early and late recurrence, chronic pain, and seroma formation were comparable between glue and suture fixation in open Lichtenstein IHR patients. Glue fixation had a shorter operating time and lower hematoma formation than suture fixation [90]. Intractable inguinal pain following laparoscopic inguinal hernia repair may be treated by laparoscopic mesh removal [91]. Surgical treatment should only be considered after adequate preoperative diagnostic evaluation of which the dermatome sensory mapping seems a useful tool for detailed neurophysiological assessment of patients with persistent post-herniorrhaphy pain undergoing remedial neurectomy [92].
Seroma

Any mesh type can cause seroma. However, large pore meshes are less likely to do so [93]. There may be a giant infected seroma following laparoscopic repair [94]. Mesh fixation with tacks or glue, a larger hernia defect, and medial defect localization presents a higher risk for seroma development in TAPP inguinal hernia repair [95]. Seroma formation is a natural process that cannot be completely prevented following laparoscopic inguinal hernioplasty, especially in patients with direct and large indirect inguinal hernias. Some intraoperative adjunctive techniques are effective in reducing clinically palpable seroma formation in select patients [96]. The simple technique of direct hernia defect closure with barbed suture in laparoscopic direct inguinal hernia repair is an effective method to reduce both incidence and volume of seroma formation without increasing the risk of recurrence, acute, and chronic pain [97].

Titanium Coated Mesh

Titanium coating of lightweight polypropylene mesh did not improve the biocompatibility compared to pure polypropylene mesh [98]. In an animal experiment comparing the development of adhesion of Proceed® mesh, Ultrapro® mesh, and TiMesh® the least formation of adhesion was noted in the TiMesh® group [99]. Absorbable layers of Parietex Composite® and C-Quir® reduce the adhesion formation compared to TiMesh® and others in short term due to phagocytosis of absorbable coatings. There was insufficient incorporation of all meshes [100]. Barriers were demonstrated to reduce postoperative adhesion in animal experiments and showed positive results in humans according to a systematic review, but none of them has been used commonly worldwide. Titanized mesh has not been included in the evaluation [101] The design of titanium coated mesh (Biocer®) may be responsible for an increased recurrence after TAPP bilateral medial inguinal hernia repair [102]. Comparable functional results (recurrence), fewer postoperative complications (seroma, foreign body sensation, sensitivity to weather changes), and improved quality of life can be achieved according to Horstmann, et al. (2006) by reducing the amount of PP in titanized meshes in TAPP inguinal hernia repair [103].

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Procedure</th>
<th>Mesh</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheidbach [104]</td>
<td>2004</td>
<td>Animal</td>
<td>Atrium® HWM, Vypro II® LWM,</td>
<td>Foreign body reaction and biocompatibility of TiMesh® are favorable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>experiment</td>
<td>Parietene® LWM, TiMesh® ELWM</td>
<td></td>
</tr>
<tr>
<td>Petter-Puchner</td>
<td>2005</td>
<td>Animal</td>
<td>TiMesh® ELWM, Vypro® + fibrin</td>
<td>No failure in tensile and burst strength, good tissue integration, and</td>
</tr>
<tr>
<td>[105]</td>
<td></td>
<td>experiment</td>
<td>sealant (FS) versus staples</td>
<td>neovascularization</td>
</tr>
<tr>
<td>Tamme</td>
<td>2005</td>
<td>TEP</td>
<td>TiMesh</td>
<td>Chronic pain and rigidity – evaluation after one year necessary</td>
</tr>
<tr>
<td>Horstmann [103]</td>
<td>2006</td>
<td>TAPP</td>
<td>Prolene® Vypro® TiMesh®</td>
<td>Comparable functional results (recurrence), fewer postoperative</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>complications (seroma, foreign body sensation, sensitivity to weather</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>changes)</td>
</tr>
<tr>
<td>Harrell [108]</td>
<td>2006</td>
<td>In vitro</td>
<td>Marlex®, PTFE, DualMesh Plus®,</td>
<td>DualMesh Plus® due to its antimicrobial coating demonstrated bactericidal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>experiment</td>
<td>DualMesh®, Composix E/X®, Proceed®,</td>
<td>properties,</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Parietex Composite®, TiMesh®,</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Ultrapro®, Vypro®</td>
<td></td>
</tr>
<tr>
<td>Schug-Pass [107]</td>
<td>2006</td>
<td>Animal</td>
<td>TiMesh® – Dual mesh® (expanded</td>
<td>TiMesh® is superior to DualMesh® in biocompatibility (adhesion,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>experiment</td>
<td>polytetrafluoroethylene)</td>
<td>shrinkage, inflammatory response)</td>
</tr>
<tr>
<td>Fortelny [109]</td>
<td>2007</td>
<td>Animal</td>
<td>TiMesh® + Glubran II®</td>
<td>Glubran II® impairs tissue integration, inflammation, and biomechanics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>experiment</td>
<td></td>
<td>of TiMesh®</td>
</tr>
</tbody>
</table>
### Table: Polypropylene Mesh Complications in Inguinal Hernia Repair

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Technique</th>
<th>Mesh Type/Sealant Combination</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Koch [110]</td>
<td>2008</td>
<td>Lichtenstein</td>
<td>TiMesh Standard PP mesh</td>
<td>Patients with the lightweight mesh had a shorter convalescence than those with the standard heavyweight mesh.</td>
</tr>
<tr>
<td>Fortelny [111]</td>
<td>2008</td>
<td>TAPP</td>
<td>Prospective – TiMesh® + Fibrin sealant (FS) Tisseel® Tissucol®</td>
<td>Significant improvement in physical health and reduction of pain with SF36 and VAS</td>
</tr>
<tr>
<td>Peeters [112]</td>
<td>2010</td>
<td>TEP</td>
<td>RCT 1 year Vypro II® – TiMesh® Marlex®</td>
<td>Negative influence on sperm motility by lightweight mesh</td>
</tr>
<tr>
<td>Schopf [113]</td>
<td>2011</td>
<td>TAPP</td>
<td>RCT Light TiMesh® Extralight TiMesh®</td>
<td>No difference in recurrence – chronic pain more in Light TiMesh®</td>
</tr>
<tr>
<td>Bittner [114]</td>
<td>2011</td>
<td>TAPP</td>
<td>RCT HVM extra light TiMesh® ELWM</td>
<td>ELWM - Less impairment of physical activity and seroma – no effect on chronic pain</td>
</tr>
<tr>
<td>Bittner [115]</td>
<td>2011</td>
<td>TAPP</td>
<td>RCT HWM MWM LWM TLW</td>
<td>HWM less postoperative convalescence but no effect on chronic pain – no difference in the LWM, MWM, TLWM</td>
</tr>
<tr>
<td>Schug-Pass [116]</td>
<td>2012</td>
<td>Experimental study</td>
<td>Fixation strength TiMesh® light, Ultrapro®, Optilene® – Tissucol®, Quixil®, Evicel®</td>
<td>No difference in fixation strength of different polypropylene meshes in an optimum combination with a fibrin glue</td>
</tr>
<tr>
<td>Fortelny [117]</td>
<td>2012</td>
<td>TAPP</td>
<td>TiMesh® Tisseel® Stapler</td>
<td>Comparable results for chronic pain and QoL</td>
</tr>
<tr>
<td>Schug-Pass [118]</td>
<td>2013</td>
<td>Experimental study</td>
<td>Fixation strength Evicel® Glubran®</td>
<td>Bioglue® and Glubran® improved adhesive strength</td>
</tr>
<tr>
<td>Köckerling [119]</td>
<td>2014</td>
<td>Evidence-based review of the literature</td>
<td>TiMesh®</td>
<td>In clinical studies, the titanium-coated polypropylene mesh shows in inguinal hernia repair certain benefits compared with the use of older heavy-weight meshes.</td>
</tr>
<tr>
<td>Peeters [120]</td>
<td>2014</td>
<td>TEP</td>
<td>RCT 3 years Vypro II® TiMesh® Marlex®</td>
<td>No decrease of sperm motility – HVM and LWM comparable QoL, chronic pain, recurrence</td>
</tr>
<tr>
<td>Prassas [121]</td>
<td>2016</td>
<td>TEP</td>
<td>Retrospective LWM Titanium HWM</td>
<td>No difference in pain, chronic pain, recurrence</td>
</tr>
<tr>
<td>D’Amore [122]</td>
<td>2017</td>
<td>Animal experiment</td>
<td>DynaMesh®, TiMesh®, C-QUR/FX®</td>
<td>The meshes reduce but do not prevent adhesion</td>
</tr>
<tr>
<td>Köhler [102]</td>
<td>2018</td>
<td>TAPP</td>
<td>Bilateral mesh – TiO2 (Biocer®)</td>
<td>High recurrence rate – redesign of mesh recommended</td>
</tr>
<tr>
<td>Dong [123]</td>
<td>2018</td>
<td>Systematic review</td>
<td>Mesh nonmesh Vypro II® TiMesh® Marlex®</td>
<td>Hernia repair with mesh in the open or laparoscopic procedure has no significant effect on male fertility</td>
</tr>
</tbody>
</table>
Table 1: In-vitro and animal experiments, clinical and randomized studies, and a systematic review including TiMesh®.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Procedure</th>
<th>Mesh Type</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yang</td>
<td>2019</td>
<td>TAPP</td>
<td>TiMesh® PPM RCT</td>
<td>No difference in seroma and foreign body sensation but shorter recovery period in TiMesh</td>
</tr>
<tr>
<td>Filiovic-Cugura</td>
<td>2020</td>
<td>Animal experiment</td>
<td>Surgisis®, Vypro II®, TiMesh®</td>
<td>Surgisis® produced more inflammation, less granuloma formation, and fibrosis, but more signs of infection compared to TiMesh®</td>
</tr>
<tr>
<td>Wirth</td>
<td>2020</td>
<td>TAPP</td>
<td>Fibrin glue versus staple fixation of extra light titanized mesh</td>
<td>No difference in perioperative complications, recurrence, and chronic pain</td>
</tr>
</tbody>
</table>

**In-Vitro and Animal Studies With Timesh**

TiMesh® shows favorable foreign body reaction, biocompatibility, no failure in tensile and burst strength, good tissue integration, and neovascularization [104,105]. TiMesh® is superior to DualMesh® in biocompatibility (adhesion, shrinkage, inflammatory response) [108]. DualMesh Plus® due to its antimicrobial coating demonstrated bactericidal properties [107]. No difference in fixation strength of different polypropylene meshes in an optimum combination with fibrin glue [116]. Bioglu® and Glubran® improved adhesive strength [118]. The meshes reduce but do not prevent adhesion [122]. Surgisis® produced more inflammation, less granuloma formation, and fibrosis, but more signs of infection than TiMesh® [125].

**Clinical Studies in IHR with Timesh**

In clinical mostly randomized controlled trials there were advantages of TiMesh® in IHR. Horstmann reported comparable functional results (recurrence), fewer postoperative complications (seroma, foreign body sensation, sensitivity to weather changes) in Prolene®, Vypro®, and TiMesh® [103]. Fortelny indicated significant improvement in physical health and reduction of pain with SF36 and Visual Analog Scale (VAS) in TiMesh® and Fibrin Sealant (Tisseel®) [111]. A negative influence in sperm motility by lightweight mesh has been reported after 1 year postoperatively but not after three years in laparoscopic TiMesh® IHR [112, 120]. Hernia repair with mesh in the open or laparoscopic procedure has no significant effect on male fertility according to a systematic review by Dong 2018 [123]. No difference in recurrence but more chronic pain has been reported in Light TiMesh® in TAPP IHR [113]. The ELW IHR has been followed by less impairment of physical activity and seroma but no effect on chronic pain in TAPP comparing HVM to extra light TiMesh® ELW [114]. HWM had less postoperative convalescence time but no effect on chronic pain. There was no difference in the LWM, MWM, and TLWM in TAPP IHRs [115]. There were comparable results for chronic pain and QoL in TAPP (TiMesh® Tisseel® versus Stapler) [117]. No difference in pain, chronic pain, or recurrence was demonstrated in TEP IHR [116]. No difference in seroma and foreign body sensation but a shorter recovery period in TiMesh® TEP was reported by Yang et al. 2019 [124]. There was no difference in perioperative complications, recurrence, and chronic pain in TAPP IHR [126]. In clinical studies, the titanium-coated polypropylene mesh shows in inguinal hernia repair certain benefits compared with the use of older heavy-weight meshes [119].

**Conclusion**

Polypropylene mesh has been successful in inguinal hernia repair for decades. However, in recent years complications of PP became evident in scientific reports and the public. Complications seem to be related to the material and structure of the mesh but also to the surgeon’s expertise and patient’s characteristics. It became evident that more complications appear long-term. The true rate of complications could be higher. There are a few clinical reports on titanium-coated mesh (TiMesh) in TAPP and TEP inguinal hernia repair. Experience with TiMesh in laparoscopic procedures long-term and in open IHR is missing. Especially about the long-term effects of coating PP with titanium we need to have a better understanding of the interaction of soft tissue and mesh. There are promising results of pure titanium mesh which need to be confirmed in further controlled clinical studies.
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5. Hernia mesh implants used ‘with no clinical evidence’ - BBC News


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