Hernia (2025) 29:105
https://doi.org/10.1007/s10029-025-03276-0

REVIEW

Mesh fixation in laparoscopic groin hernia repair: a comprehensive review of techniques and devices

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Received: 18 November 2024 / Accepted: 19 January 2025

Abstract

Purpose Laparoscopic groin hernia repair has increased in popularity in recent years. Many laparoscopic mesh fixation techniques and devices are available, but there is a lack of high-certainty evidence favoring one fixation technique over another. This narrative review aimed to provide a comprehensive summary detailing the available mesh fixation techniques and devices used in laparoscopic groin hernia repair.

Methods Information about mesh fixation techniques and devices was searched in PubMed, groin hernia guidelines, and medical technology companies webpages.

Results This review outlines various mesh fixation techniques, materials, and their features in laparoscopic groin hernia repair. We have summarized and presented in detail the available information on both penetrating and non-penetrating mesh fixation techniques, including the option of not fixating the mesh. Penetrating mesh fixation includes tacks, staples, and sutures. Tacks vary in size, absorption time, and shape and can be further categorized into absorbable and permanent materials. Additionally, this review describes two types of permanent titanium staples and the use of permanent and absorbable sutures as mesh fixation. Non-penetrating mesh fixation includes self-fixating mesh and glue. The types of glue are cyanoacrylate glue and fibrin sealant. While fibrin sealant requires careful thawing from a frozen state before use, cyanoacrylate glue offers easier storage but poses a risk of exothermic reaction with the surrounding tissue. Self-fixating meshes have an adhesive side made of microgrips or adhesive material, and a permanent side.

Conclusion This review provided a comprehensive overview of the various mesh fixation techniques and devices in laparoscopic groin hernia repair.

Keywords Groin hernia · Mesh fixation · Laparoscopic surgery · TAPP · TEP

Introduction

The lifetime risk of inguinal hernia repair is 27% for males and 3% for females [1], and it is estimated that 20 million inguinal hernia repairs are performed worldwide annually [2]. Laparoscopic groin hernia repairs are rising in popularity in many countries [3, 4] due to the benefits concerning acute and chronic pain as well as recovery time [5, 6]. Despite the many patients with groin hernia who receive laparoscopic repair, the international groin hernia guideline does not provide a strong recommendation regarding laparoscopic mesh fixation [5]. There are two main types of laparoscopic groin hernia repairs: the transabdominal preperitoneal (TAPP) repair and the totally extraperitoneal (TEP) repair [7], and the guideline recommends mesh fixation in patients with large medial hernias undergoing either TAPP or TEP repair to reduce the risk of recurrence [5]. However, this recommendation is based on very low certainty of evidence [5]. The guideline also states that mesh fixation is likely unnecessary in most TEP repairs, based on moderate certainty of evidence [5]. These recommendations are based on no significant difference in chronic pain, acute pain, or recurrence when comparing fixation and no fixation of mesh [5]. For TAPP repair, there is insufficient evidence about the risk of recurrence to determine whether mesh fixation is necessary [5]. The types of mesh fixations can be classified into tissue penetrating and non-penetrating mesh

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Published online: 19 February 2025

fixation techniques. Penetrating fixation techniques include tacks, staples, and sutures [5], and non-penetrating fixation methods include glue and self-fixating mesh [5]. Additionally, there is the option of no fixation [5].

In both TAPP and TEP repairs, the mesh is placed anatomically in the same manner in the preperitoneal space [8, 9]. The difference between TAPP and TEP repairs lies in the surgical approach. TAPP repair employs an intraperitoneal approach, which involves opening of the peritoneum. The mesh is placed in the preperitoneal space, and surgery is completed by closing the peritoneum, usually with the same method as used for mesh fixation [9]. Conversely, TEP repair is performed entirely in the preperitoneal cavity, meaning there is no entering of the abdominal cavity. Therefore, TEP repair does not need closure of the peritoneum [8]. A recent Cochrane review has demonstrated no difference in chronic pain or recurrence between TAPP and TEP repairs [10], but it remains unclear whether mesh fixation and peritoneal closure have an influence on this outcome.

All types of fixation techniques can be used for both TAPP and TEP repairs. Many surgeons prefer to fixate the mesh, particularly during TAPP repairs [11]. It remains uncertain which fixation technique is most advantageous for patients [5], making the choice of mesh fixation likely to be based on surgeon's preference and local expertise. This narrative review aimed to provide knowledge about the available mesh fixation techniques and devices used in laparoscopic groin hernia repairs [9].

Methods

Information about mesh fixation techniques and devices was first sought in recent groin hernia guidelines [5, 6] and in PubMed. The international groin hernia guideline from 2018 [5] included studies up to 2015. Therefore, PubMed was searched for new relevant narrative and systematic reviews, observational studies, and randomized controlled trials (RCTs) in the period January 2015–September 2024. The search string consisted of the terms "groin hernia" AND "laparoscopic repair" AND "mesh fixation" [12]. Furthermore, we searched medical technology companies webpages for product information. When information on the webpage was missing or insufficient, we contacted the sales representative by email or phone to access further information. Data from brochures and product instructions received by email but not being available online were included in this review and are referenced as "personal contact". We included only mesh fixation devices for which information was available in English or Scandinavian languages. Formerly used mesh fixation devices that, to the best of our knowledge, are no longer commercially available were excluded from the review.

Tacks

Tacks can be defined as a single use, deployable penetrating device for mesh fixation. Tacks can be divided into permanent and absorbable tacks. Table 1 presents a detailed overview of the appearance, materials, and size of tacks used in

Table 1 Tack overview. PLGA: poly (glycol-co-L-lactide); PEED: polyetheretherketone. ProTack™ (Medtronic), Profound™ N (Meril), CapSure™ (BD), PermaFix™ (BD), AbsorbaTack™ (Medtronic), ReliaTack™ (Medtronic), SorbaFix™ (BD), Profound™ A (Meril), OptiFix™ (BD), and SecureStrap™ (Ethicon, Johnson & Johnson). *ReliaTack™ has two available sizes

Tack name	Material	Design	Tip	Cap/head	Length, mm
Permanent					
ProTack™ [13, 76]	Titanium	Helical coil	Sharp	None	3.9
Profound™ N [77]	Titanium	Helical coil	Sharp	None	3.8
CapSure™ [13]	Stainless steel	Helical coil	Sharp	Integrated PEED cap (17.6 mm^2 including circle in middle)	4.2
PermaFix™ [14, 76]	Polyacetal	Screw with hollow core	Blunt	Smooth head (17.6 mm^2)	6.7
Absorbable					
AbsorbaTack™ [17, 76]	PLGA	Screw	Sharp	Round head with proximal wings (8.6 mm^2)	5.1
ReliaTack™ [16, personal contact]	PLGA	Screw	Sharp	Smooth head (unknown mm^2)	5.1/7.0*
SorbaFix™ [18, 76, 78]	Poly (D, L)-lactide	Screw with hollow core	Blunt	Rounded square (17.6 mm^2)	6.7
Profound™ A [24]	Poly (lactide-co-lactide)	Screw	Sharp	Round head with proximal wings (16.5 mm^2)	5.2
OptiFix™ [20, 23, 79]	Poly (D, L)-lactide	Arrow with hollow core Barbs on body	Sharp angled tip with barbs	Smooth (9.0 mm^2)	6.7
SecureStrap™ [19, 80]	PLGA and polydioxanone	U-shape	Two sharp tips with barbs	Smooth (1.8 mm^2)	6.7

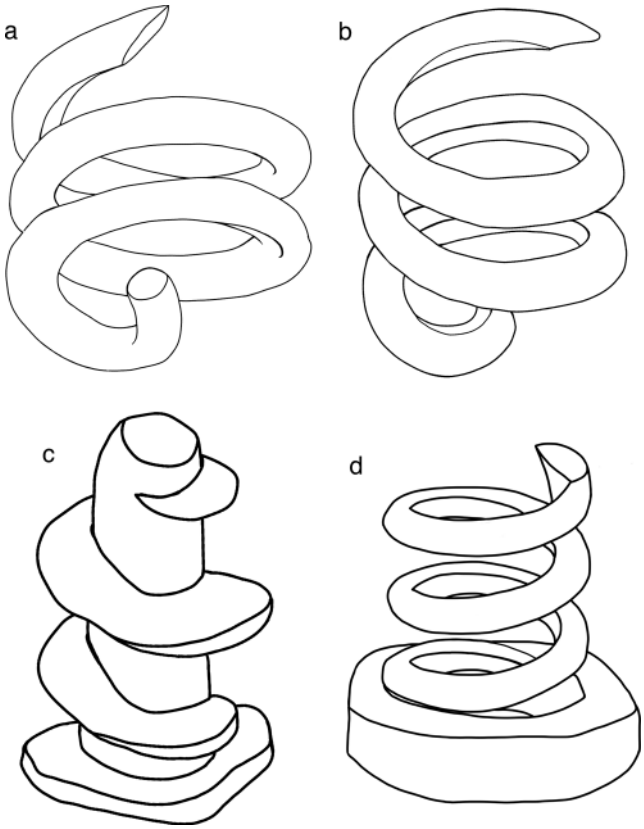

Fig. 1 Permanent tacks. **a**: ProTack™ (Covidien, Medtronic); **b**: Profound™ N (Meril); **c**: CapSure™ (BD); **d**: PermaFix™ (BD)

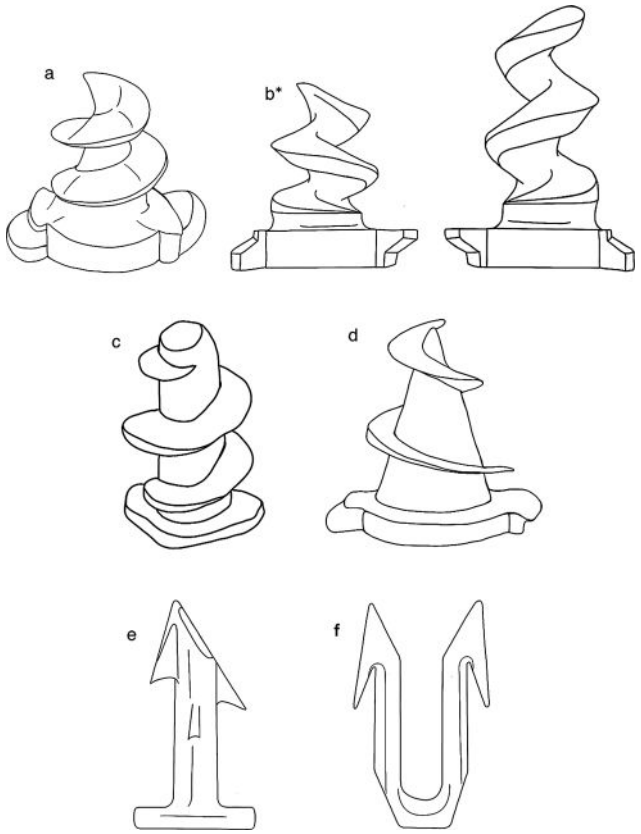

Fig. 2 Absorbable tacks. **a**: AbsorbaTack™ (Medtronic); **b**: ReliaTack™ (Medtronic); **c**: SorbaFix™ (BD); **d**: Profound™ A (Meril); **e**: OptiFix™ (BD); **f**: SecureStrap™ (Ethicon, Johnson & Johnson). *ReliaTack™ has two available sizes

laparoscopic groin hernia repair. Illustrations of the various tacks are shown in Figs. 1 and 2.

Four permanent tacks were identified: ProTack™, Profound™ N, CapSure™, and PermaFix™. The general design of a permanent tack features a helical coil with a sharp tip. The only exception to this is the PermaFix™, which is shaped like a screw with a blunt tip. Two of the permanent tacks have either a cap or a head: The CapSure™ has a cap made of polyetheretherketone, which is stated to prevent adhesions [13], whereas PermaFix™ has a soft head and the entire tack consists of polyacetal [14]. The permanent tacks vary in material: ProTack™ and Profound™ N are constructed from titanium, CapSure™ is made of stainless steel, and PermaFix™ consists of polyacetal, a molded polymer-based material [15].

The available absorbable tacks are AbsorbaTack™, ReliaTack™, SorbaFix™, ProFound™, OptiFix™, and SecureStrap™. Most of the absorbable tacks are designed as a spiral screw [16–18]. However, OptiFix™ is designed like an arrow with barbs, and SecureStrap™ has a U-shaped form with two sharp tips with barbs [19]. All absorbable tacks have sharp tips, except for SorbaFix™, which has a blunt tip. Optifix™ and SorbaFix™ have a hollow design, which is stated to enhance integration of the tacks into the tissue [20, 21]. Each of the absorbable tacks has a smooth cap. All six tacks consist in general of polymer of glycolide and/or lactide, with precise chemical details listed in Table 1. All tacks have an absorption time of around one year, except for SecureStrap™, which can remain for up to 18 months [22].

The trocar size for both permanent and absorbable tacks is 5 mm. Optimal placement and strength of a tack are reached by pressing down externally on the abdominal wall [23] to ensure the tack is inserted perpendicularly (at a 90-degree angle) into the tissue [15, 24]. When applying PermaFix™ and AbsorbaFix™, a sharp tip from the instrument is inserted into the tissue, but this tip retracts as the screw is inserted in the tissue, leaving no sharp components behind [14, 21]. The length of the tacks ranges from 3.8 mm to 7.0 mm, with a median of 5.2 mm. When using penetrated fixation methods, including tacks, staples, and sutures, there is a risk of damaging underlying nerves and vessels in the exposed areas [8, 9]. Therefore, it is prohibited to use penetrating fixation in the triangle of doom and the triangle of pain [9].

Staples

The two brands of staples available are Endopath® Endoscopic Multifeed Stapler (EMS) by Ethicon and Multifire Endo Hernia™ (Multifire) by Medtronic [25, 26]. Figure 3 illustrates the general design of a staple that has been inserted into the tissue. Staples function similarly to a paperclip: they are open when applied and then closed by the applicator upon insertion. Both staplers are made of titanium, making them a permanent fixation method [27]. EMS is 5.3 mm in length [28], whereas Multifire comes in two sizes: 4.0–4.8 mm in length [29]. The trocar size for EMS is 10–11 mm [29], whereas Multifire requires a trocar size of 12 mm [28].

Sutures

Both absorbable and permanent sutures can be used for mesh fixation [30–32], and the thread can be monofilament or braided. The variety of available suture types is extensive, and the choice largely depends on the individual surgeon's preference. Mastering the skill of suturing the mesh may be more technically demanding compared with tacking the mesh during a TAPP or TEP repair. Typically, one to three stitches are used for sutured mesh fixation [33, 34], but there is no consensus regarding the number of stiches or their location. If choosing to suture the mesh during TAPP repair, the closure of the peritoneum can also be done by sutures to reduce the costs.

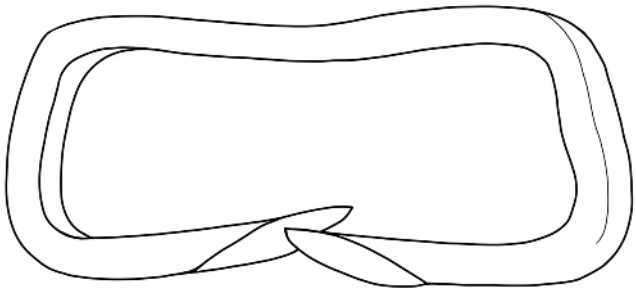

Fig. 3 Illustration of a staple

Glue

Cyanoacrylate glue and fibrin sealant are the two types of glue used to fixate the mesh in laparoscopic groin hernia repair [35]. Tables 2 and 3 list the individual features of the different glues, including components and storage conditions. Cyanoacrylate glue is synthetic, whereas fibrin sealant is biological. This review includes only brands used for mesh fixation in laparoscopic groin hernia repair. Glue has many indications besides mesh fixation, such as wound closure, plastic surgery, cardiovascular surgeries, and control of hemorrhage [35, 36].

Table 2 presents the precise chemical components of the different cyanoacrylate glues. Typically, the synthetic cyanoacrylate glues have one of two different active components: hexyl-2-cyanoacrylate, used in Ifabond® [37], and butyl-2-cyanoacrylate, used in Histoacryl® [36], Glubran® 2 [38], and LiquiBandFIX8® [39]. The solidification process, or polymerization, occurs when cyanoacrylate mixes with weak bases, such as tissue. This activates the adhesive component in the cyanoacrylate glue. Cyanoacrylate glue is generally applied by dropping the glue on the mesh or

Table 2 Cyanoacrylate glue. Color: D&C violet No. 2 dye. Histoacryl® (B. Braun), Glubran® 2 (GEM), Ifabond® (Peters Surgical), and LiquiBand-Fix8® (Advanced Medical Solutions)

Glue name	Components	Color	Storage (˚C)	Absorption (months)
Histoacryl® [36]	N-butyl-2-cyanoacrylate	Optional	<22	24
Glubran® 2 [38, personal contact]	N-butyl-2-cyanoacrylate and metacryloxy sulfolane	No	2–8	6
LiquiBandFIX8® [39]	N-butyl-2-cyanoacrylate, butalated hydroxyanisole, n-butyl cyanoacetate and formaldehyde	D&C Violet No.2	5–25	Unknown
Ifabond® [37, 44, 81]	N-hexyl cyanoacrylate	No	<5	12

Table 3 Fibrin sealant. Tisseel® (Baxter International Inc), Evicel® (Ethicon, Johnson & Johnson), and Vivostat® Fibrin (Vivostat)

Name	Component 1	Component 2	Coverage (cm^2/ml)	Storage (˚C)	Durability at 22 ˚C
Tisseel® [45, 47]	- Human fibrinogen - Aprotinin	- Human thrombin - Calcium chloride	5	≤ -20	4 h
Evicel® [49]	- BAC2: human fibrinogen and human protein	- Human thrombin - Calcium chloride	20	≤ -18	24 h
Vivostat® Fibrin [50]	120 ml blood turns into 5 ml fibrin sealant (after 24 min). Can be used up till 24 h after production		Unknown	Unknown	Unknown

applying it directly on the tissue [40]. When using Glubran® 2, it is also possible to spray it by using a specialized device [41]. Cyanoacrylate glue is ready to use directly from storage, requiring no mixing. According to the manufacturer, the glue must be applied directly onto the mesh for pores sizes > 1 mm and directly to the tissue for pore sizes < 1 mm [36]. The manufacturer also recommends holding the mesh in place for 30 s to fully ensure that the adhesive function works [36]. A possible disadvantage of cyanoacrylate glue is that an exothermic process can occur during the polymerization, and the heat can in theory lead to tissue damage [42, 43]. Additionally, the polymerization rate can be rapid, and solidification of the glue in the laparoscopic applicator may occur, resulting in blockage of the cannula or tip of the instrument [44]. Ifabond®'s molecular structure is longer than the other glues, which in theory slows down the polymerization process and makes it less exothermic. Thus, Ifabond®'s temperature is reported to increase by a maximum of 2 °C (35.6 °F) during polymerization [personal contact]. While Histoacryl®, Glubran® 2, and LiquiBandFIX8® all are made of N-butyl-2-cyanoacrylate, Histoacryl® is the only glue that solely consists of this material, and it is recommended to coat instruments with either dimethylformamide or acetone to prevent clotting of the instrument from Histoacryl® [36]. Both Glubran® 2 and LiquiBandFIX8® contain additional components to slow down the polymerization process [39, personal contact]. Regarding storage of cyanoacrylate glues, Histoacryl® should be stored at room temperature away from direct sunlight, LiquiBandFIX8® at 5–25 °C (41–77 °F) away from direct sunlight [36, 39], information on Ifabond® was unavailable, and Glubran® 2 should be stored at cooled temperatures between 2 and 8 °C (35.6–46.4 °F) [personal contact]. If Glubran® 2 reaches a temperature of 22 °C (71.6 °F), it remains viable for only 48 h [personal contact].

The biological glue is often referred to as fibrin sealant. Table 3 provides an overview of the brands available for mesh fixation in laparoscopic groin hernia repair. Fibrin sealants consist of two separate components: fibrinogen and thrombin combined with calcium chloride [45]. These two components mix during application, initiating the fibrinolysis process [46], which makes the glue adhesive. Fibrin sealant is fully bioregenerative within two weeks [47]. Different fibrin sealant brands for mesh fixation are called Tisseel®/Tissucol® [48], Evicel® [49], and Vivostat® Fibrin [50]. Evicel®'s authorization has been withdrawn at the manufacturer's request in August 2024 [51], which previously was marketed as Quixil® in the European Union and Crosseal™ in the United States [52]. According to the manufacturer, fibrin sealant must be stored frozen, and further precautions exist regarding thawing [45]. The manufacturer states that Tisseel® should neither be stored nor thawed in a refrigerator [45]. For Tisseel®, faster thawing can be achieved using a sterile water bath if the temperature is kept below 37 °C (98.6 °F). When thawing Tisseel® at room temperature, the temperature should not exceed 25 °C (77 °F) [45]. The manufacturer further states that shortly before use, Tisseel® should be heated further until reaching a temperature of 33–37 °C (91.4–98.6 °F) [45]. Generally, the fibrin sealant can be applied either by spray or by drop [45]. When spraying the fibrin glue, the tip of the applicator should maintain a 4–10 cm distance from the tissue [47, 49, 53], and the glue should be applied in a thin layer.

Lastly, Vivostat® Fibrin is an autologous fibrin sealant that differs from cyanoacrylate glues and fibrin sealants as it is made from the patient's own blood. It requires 120 ml of the patient's blood and takes approximately 24 min to prepare [50]. It is possible to prepare the glue 24 h in advance [50].

Self-fixating mesh

Self-fixating mesh combines both a mesh and a fixation in one product. There are two types available: self-gripping mesh and mesh with adhesive material.

ProGrip™ from Medtronic is a self-gripping mesh with microgrips [54]. One side of the mesh has 36 microgrips per cm^2 made of monofilament polylactic acid [54], and the microgrips fixate to the tissue by contact pressure [personal contact]. The other side of the mesh consists of a permanent material made of monofilament polyethyl terephthalate, a type of polyester [54]. The weight of the mesh before reabsorption is 89 g/m^2, while the weight after resorption of the grips is 49 g/m^2 [54], classifying it as a lightweight mesh [55]. The absorption time for the microgrips is approximately 15 months [personal contact].

Adhesix™ from BD is a self-fixating mesh with adhesive material, consisting of two sides [personal contact]. One side has a coating of polyethylene glycol and polyvinylpyrrolidone, which becomes adhesive in contact with moisture, and the other side is a knitted mesh made of monofilament polypropylene [56]. The mesh weight after reabsorption is < 40 g/m^2 [56], classifying it as a lightweight mesh [55]. The adhesive part reabsorbs within seven days [56].

Placement of the self-gripping and adhesive mesh can be challenging in laparoscopic hernia repair, requiring practice to ensure proper fixation on the tissue [personal contact]. To avoid activation of adhesive layers outside of the body, and subsequent difficulty of introduction and placement, adhesive mesh types must be kept dry beforehand [personal contact]. Various techniques for placing the mesh have been suggested—rolling it like a cigarette or using the "Swiss roll" before placing the mesh [57]. When "Swiss rolling"

the mesh, it is rolled up and secured with a suture [57]. According to the manufacturers' recommendations, the mesh should be inserted through a 12 mm trocar size due to its size when rolled up [57, personal contact].

No fixation of mesh

Lastly, the final option is non-fixation of the mesh, leaving it in the preperitoneal space without fixating it. Far from all surgeons routinely fixate the mesh in TEP repair, and data from the Herniamed registry showed that no mesh fixation was used in 94% of the TEP repairs [8, 58]. While fixation of the mesh is more common during TAPP repair, no fixation is also a viable option [11, 58]. The reasons for choosing fixation or no fixation of the mesh is not well described in the literature, but one theoretical explanation of choosing no fixation in TEP could be due to the differences in TAPP and TEP [8, 9]. In TEP, there is no opening or closure of the peritoneum, which may facilitate a more solid placement of the mesh even if it is not fixated. In TAPP, surgeons might be more likely to fixate the mesh to avoid mesh displacement when closing the peritoneum. The HerniaSurge guideline recommends fixation of the mesh when repairing large medial hernias, although this recommendation is based on very low certainty of evidence [5]. In general, the available studies that are included in these guidelines have a short follow-up time with a maximum 36 months, which weakens the reliability of the conclusions regarding the recurrence risk.

Discussion

This narrative review outlines the various mesh fixation techniques and devices used in laparoscopic groin hernia repair. The covered techniques include penetrating and non-penetrating fixation methods, as well as the option of no fixation of the mesh. Numerous fixation options exist without clear recommendations. Permanent and absorbable tacks differ in the penetration depth, as well as in the design and material. Absorbable tacks are typically made of polymer derived from glycolide and/or lactide with a typical absorption time of one year. Other penetrating fixation options are permanent staples and permanent or absorbable sutures. Glue and self-fixating mesh make it possible to fixate the mesh without penetrating the groin tissue, allowing fixation in the triangles of doom and pain. Two types of glue are used to fixate the mesh: the synthetic cyanoacrylate glues and the biological fibrin sealants.

Despite the importance of this topic, the available information on mesh fixation techniques and devices is limited. We contacted the manufacturers for additional information whenever possible, but it was overall a difficult process and not always possible to obtain the requested information. Access to such information should be more publicly available since an understanding of the different types of mesh fixation is essential for the medical professionals using them.

Various fixation techniques have been compared in previous systematic reviews and RCTs, such as tacks versus sutures [33, 59], staples and/or tacks versus glue [60–62], permanent versus absorbable tacks [63], cyanoacrylate glue versus fibrin sealant [64], and mesh fixation versus no fixation [65–74]. Research indicates no clinically or statistically significant differences in chronic pain and recurrence rates when comparing different mesh fixation methods [61–63]. It is difficult to reach high certainty of the evidence because of clinical and methodological heterogenicity among studies. "Many outcomes in the conducted RCTs cannot be evaluated sufficiently due to different definitions and measurements of chronic pain, differences in intervals of follow-up times, and differences in duration of follow-up [33, 59–74]. Furthermore, the RCTs have a follow-up time from 3 to 38 months [33, 59–74]. This is a relatively short follow-up period as recurrence rates tend to increase steadily during at least the first five years postoperatively [75].

The economic aspect is an important factor influencing the choice and availability of mesh fixation devices. Cost likely influences the availability of fixation methods. Generally, tacks and glue tend to be more expensive than suture or no fixation of mesh. Some studies have shown significantly shorter operating time using tacks and glue fixation compared with sutures [33, 59]. While these times are influenced by the surgeons' skills, they can also impact the economic considerations of the choice of mesh fixation. In TAPP repair, peritoneal closure is essential. Peritoneum can be closed with tacks, staples, sutures, or glue. To minimize costs, it is most intuitive to use the same mesh fixation material when closing the peritoneum. For example, if the mesh is fixated with glue, the peritoneum can also be glued. Likewise, if the mesh was sutured or not fixated at all, peritoneum can be sutured as well due to the lower cost compared with glue and tacks.

In conclusion, this review provides an overview of penetrating and non-penetrating mesh fixation techniques and devices in laparoscopic groin hernia repair, as well as the possibility of choosing no mesh fixation. We noticed a frequent lack of publicly available necessary product information, making it difficult and sometimes impossible to easily find such information for the clinician. Additionally, while various mesh fixation options exist, robust evidence regarding critical outcomes remains scarce.

Declarations

Competing interest This study received no financial support from extramural sources.

Conflict of interest Patricia Rancke-Madsen, Stina Öberg, and Jacob Rosenberg declare that they have no conflict of interest.

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