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ORIGINAL ARTICLE

Prophylactic mesh versus primary closure in emergency and elective surgeries: a systematic review and meta-analysis of randomized clinical trials

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Abstract

Purpose Incisional hernia is one of the most common post-operative complications. Previous studies showed that prophylactic mesh placement in laparotomy closure is safe and reduces the incidence of incisional hernia. We aimed to perform a meta-analysis comparing post-operative complications after the use of prophylactic permanent mesh placement versus primary closure in patients undergoing elective or emergency laparotomies.

Methods A systematic review of Cochrane Central Register of Controlled Trials, Embase and PubMed was performed in April 2024. Only randomized clinical trials were included. 1,234 studies were imported for screening. 280 were duplicated reports, 923 were excluded for irrelevancy and 16 were excluded after full-text review. Data were extracted in accordance with PRISMA guidelines and pooled by a random-effects model. The primary outcome was incidence of incisional hernia. Secondary outcomes included post-operative complications and period of hospitalization.

Results Fifteen studies and 2,108 patients were included. Incisional hernia incidence was different between groups (risk ratio [RR] 0.30; 95% CI 0.21–0.43; $p < 0.00001$; $I^2=39\%$). This finding was confirmed in a subgroup analysis of elective (RR 0.29; 95% CI 0.18–0.46; $p < 0.00001$; $I^2=48\%$) versus emergency laparotomies (RR 0.28; 95% CI 0.19–0.43; $p = 0.0001$; $I^2=0\%$). There was no significant difference in incisional hernia incidence by locals of mesh placement. Secondary outcomes had shown no statistically significant difference between groups, except for seroma wherein primary closure had lower events (RR 1.80; CI 95% 1.21–2.68; $p = 0.38$; $I^2=7\%$).

Conclusion In patients undergoing laparotomy, prophylactic permanent mesh placement is associated with a significant reduction on incidence of incisional hernia as compared to primary closure.

Keywords Incisional hernia · Laparotomy · Surgical mesh · Postoperative complications

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Introduction

Incisional hernia (IH) is a common complication following midline laparotomy. A systematic review reported an overall incidence of 12.8% for IH two years after midline incision, with one-third of these patients requiring surgical repair [1]. Interventions to correct IH results in substantial health care costs, leading to $6.3 billion in hospital charges in the USA over two years [2].

Patients with IH are usually part of high-risk population, with more than half having at least one comorbidity [3]. Groups with body mass index (BMI) of 27 kg/m² or higher have more than a 30% chance of developing IH [4]. Moreover, obese patients are more likely to require emergency surgical repair and have more overall and wound-related complications after IH repair when compared to those with BMI < 30 [3, 5]. In addition, patients with surgically repaired abdominal hernias often experience deterioration in quality of life, particularly in the first 4 months post-operative (PO) [6].

Previous meta-analysis has shown a significant difference in the IH incidence in prophylactic mesh placement (PMP) group when compared to primary closure (PC) in laparotomy closure [7–11]. However, these studies included both permanent synthetic mesh and absorbable meshes and also included observational studies, which do not provide clear evidence of what type of mesh should be used. As a result, most surgeons and hospitals have not yet adopted PMP as a standard protocol.

Currently, there is no specific suture material or preference for continuous versus interrupted techniques that demonstrated clear superiority for laparotomy closure. However, to reduce the risk of IH, the recommendation is to use a slowly absorbable suture in a continuous small-bites suturing technique, which implies a suture length to wound length ratio of at least 4:1, maintaining low tension on the suture. Additionally, for prophylactic mesh augmentation, it is suggested to use a permanent synthetic mesh, although in a very low quality of evidence [12].

This is the first systematic review and meta-analysis that includes only randomized controlled trials assessing the efficacy of PMP regarding only permanent synthetic mesh or partial resorbable mesh, efficient and cheaper materials available in hospitals worldwide [13].

Materials and methods

Eligibility criteria

The studies included in this meta-analysis must met all the following eligibility criteria: (1) randomized clinical trials (RCT); (2) comparing prophylactic mesh to PC; (3) use of a permanent synthetic mesh or a partial resorbable mesh; (4) in patients undergoing elective or emergency laparotomies; and (5) reporting any of the outcomes of interest. We excluded studies with: (1) not randomized; (2) no control group; (3) use of absorbable mesh or not specified; or (4) overlapping patient populations. No limits were set for year of publication and outcomes reported.

Search strategy and data extraction

We performed a systematic review on PubMed, EMBASE, and Cochrane Central Register of Controlled Trials in April 2024 with the following medical subject heading terms: 'laparotomy', 'abdominal wound closure techniques', 'surgical mesh', 'non-absorbable mesh', 'synthetic mesh', 'suture techniques', 'primary closure', 'abdominal wall closure'. The references from all included studies and previous review were also manually searched. Two authors (AV, CS) independently extracted the data following pre-defined search criteria and quality assessment.

Endpoints and subgroup analyses

The primary outcome of interest was IH, and the secondary outcomes included seroma, hematoma, wound infection, evisceration, postoperative mortality, period of hospitalization and pain. We performed subgroup analyses of (1) elective and emergency laparotomies, (2) mesh position, namely sublay, onlay and intraperitoneal onlay mesh position (IPOM), and (3) different types of mesh, namely permanent synthetic mesh and partial resorbable mesh.

Quality assessment

RCTs were appraised with Cochrane's tool for assessing bias in randomized trials, wherein studies are scored as high, low, or unclear risk of bias in five domains: selection, performance, detection, attrition, and reporting. Publication bias was investigated with funnel-plot analysis of the primary outcomes.

Statistical analysis

The systematic review and meta-analysis were performed in accordance with recommendations from the Cochrane Collaboration and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement. Pooled treatment effects for binary endpoints were compared using risk ratio (RR) with 95% confidence intervals. Heterogeneity was examined with Cochran Q test and I^2 statistics. A Mantel-Haenszel random-effects model was used. Review

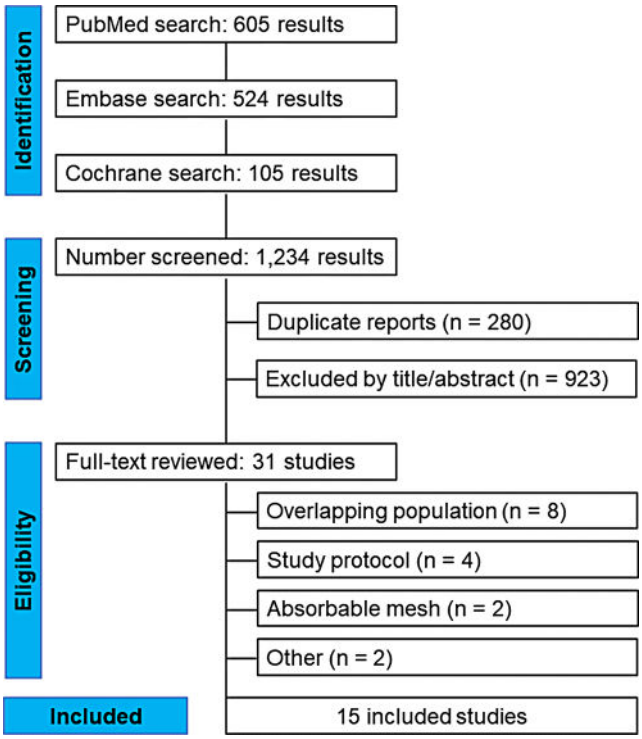

Fig. 1 PRISMA flow diagram of study screening and selection

Manager 5.1 (Nordic Cochrane Centre, The Cochrane Collaboration, 110 Copenhagen, Denmark) was used for statistical analysis.

Results

Study selection and characteristics

The initial search yielded 1,234 results. After removal of duplicate records and unrelated studies, 34 remained and were fully reviewed for the inclusion criteria (Fig. 1). After exclusion of studies, we included 15 RCTs [14–28] with a total of 2,108 patients were included in the review. PMP was utilized in 1,178 patients (55,88%). The mean age was 63,28 ± 10,42 years, BMI was 29,99 ± 5,35 kg/m² and mean follow-up was 21,34 ± 11,06 months. Baseline characteristics were comparable between groups (Table 1). Four studies used a composite mesh: one composed solely of permanent synthetic materials (polypropylene plus polyvinylidene fluoride)[23], and three consisting of a combination of permanent synthetic and partial resorbable materials, including porcine collagen surface plus polyethylene [16], polyactic acid microgrips plus polyester [26] or poliglecaprone-25 plus polypropylene [28]. The other eleven studies opted for a simple polypropylene mesh.

In seven studies the sublay technique was performed, five used onlay technique, two used an IPOM method, and one study had two intervention arms, for onlay and sublay position. The sublay technique placed the mesh between the posterior rectus sheath and rectus muscle; onlay is placed anterior to the fascia overlying the repair and affixed to the anterior abdominal wall fascia; IPOM the mesh is placed in an intraperitoneal position. Eleven studies included only

Table 1 Baseline characteristics of included studies

Study	Year	No of patients	I/C*	No of Male (%)†	Age (mean)	Follow-up (months)
Abo-Ryia	2013	64	32/32	13 (20)	37.7	48.5
Bevis	2010	80	37/43	(90)	73	23.8
Brosi	2017	267	131/136	116 (43)	64.5	24
Caro-Tarrago	2014	160	80/80	90 (56)	65.8	13.6
El-Khadrawy	2009	40	20/20	18 (45)	47.7	36.7
García-Ureña	2015	107	53/54	64 (60)	63.6	24
Gutierrez De La Peña	2003	88	44/44	(67)	64.3	36
Honig	2022	69	34/35	94 (90)	69.2	24
Jairam	2017	480	373/107	224 (47)	64.5	23
Kohler	2019	149	68/81	102 (68)	66	17.7
Lima	2020	115	63/52	66 (57)	63.1	01
Muysoms	2016	114	56/58	105 (92)	72	24
Pizza	2021	200	100/100	86 (43)	66	24
Strzelczyk	2006	74	36/38	47 (63)	39.1	28
Ulutas	2023	101	51/50	59 (58)	56	12.6

*I/C, intervention/control

† Male sex was reported using total number and percentage. Two studies reported only the percentage

elective laparotomy patients, three [24, 26, 28] included only emergency laparotomy patients, and one included both [19]. Operative details are provided in Table 2.

Pooled analysis of all studies

The incidence of IH was reported in 14 studies, including 1,119 (90,68%) patients. Only one trial [24] published a 30-day postoperative result for 115 patients, where the primary outcome was fascial dehiscence and IH would not be assessed until 1-year time point. IH was significantly lower in PMP group (107/1089; 9,82%) as compared to PC (241/878; 27,44%), however statistically significant heterogeneity was detected for this comparison (RR 0.30; 95% CI 0.21–0.43; p = < 0.0001; I²=39%; Fig. 2). A sensitive analysis excluding studies one by one to find those responsible to the heterogeneity, found that two studies [17, 22] were responsible for higher I² value.

Post-operative mortality, included in-hospital to 30-day mortality, was reported in seven studies, wherein two [26, 27] no event occurred in intervention or control group. The incidence of post-operative mortality was low (PMP, 3,09%; PC, 4,93%) and not significantly different between groups (RR 0.58; 95% CI 0.32–1.08; $p = 0.08$; I²=0%; Fig. 3).

Post-operative complications including seroma, hematoma, wound infection, and evisceration were analyzed. Hematoma was shown in six studies, however the incidence of hematoma was not significantly different in both groups (RR 0.96; CI 95% 0.40–2.33; $p = 0.93$; I² 0%; Fig. 4), as well as evisceration. This latter outcome data was reported in eight studies, but only six studies presented at least one event, revealing a low incidence (PMP, 6/429, 1,40%; PC, 17/420, 4,05%) and no difference statistically significant (RR 0.49; CI 95% 0.16–1.56; $p = 0.23$; I²=24%; Fig. 5).

Seroma was the only complication where control group were favorable. Thirteen studies gave the data and incidence

Table 2 Surgery characteristics of included studies

Study	Type of surgery	Mesh placement site	Mesh type	Fascial suture	Mesh suture fixation
Abo-Ryia 2013 [14]	Elective	Sublay	Polypropylene	Continuous(Prolene)	Interrupted
Bevis 2010 [15]	Elective	Sublay	Polypropylene	Continuous (non-absorbable)	Interrupted (polypropylene)
Brosi 2017 [16]	Elective	IPOM	Porcine collagen plys polyethylene	Continuous (PDS*)	Interrupted (polypropylene)
Caro-Tarrago 2014 [17]	Elective	Onlay	Polypropylene	Continuous (PDS)	Interrupted (polyglactin)
El-Khadrawy 2009 [18]	Elective	Sublay	Polypropylene	Continuous (polypropylene)	Interrupted
García-Ureña 2015 [19]	Elective or Emergency	Onlay	Polypropylene	Continuous (poly-4-hydroxybutyrate)	Interrupted (PDS)
Gutierrez De La Peña 2003 [20]	Elective	Onlay	Polypropylene	Continuous (non-absorbable monofilament)	Interrupted (absorbable material)
Honig 2022 [21]	Elective	Onlay	Polypropylene	Continuous (PDS)	Interrupted (PDS)
Jairam 2017 [22]	Elective	Onlay and Sublay	Polypropylene	Continuous (PDS)	Fibrin sealant
Kohler 2019 [23]	Elective	IPOM†	Polyvinylidene fluoride and polypropylene	Continuous (PDS)	Interrupted
Lima 2020 [24]	Emergency	Sublay	Polypropylene	Continuous (PDS)	Continuous (Polyglactin)
Muysoms 2016 [25]	Elective	Sublay	Polypropylene	Continuous (PDS)	Interrupted (Polyglactin)
Pizza 2021 [26]	Emergency	Sublay	Polylactic acid plus polyester	Continuous (PDS)	Self-fixating
Strzelczyk 2006 [27]	Elective	Sublay	Polypropylene	Continuous (PDS)	Interrupted
Ulutas 2023 [28]	Emergency	Onlay	Polypropylene plus Poliglecaprone 25	Continuous (PDS)	Continuous (polypropylene)

*PDS: Polydioxanone; †IPOM: Intraperitoneal Onlay Mesh

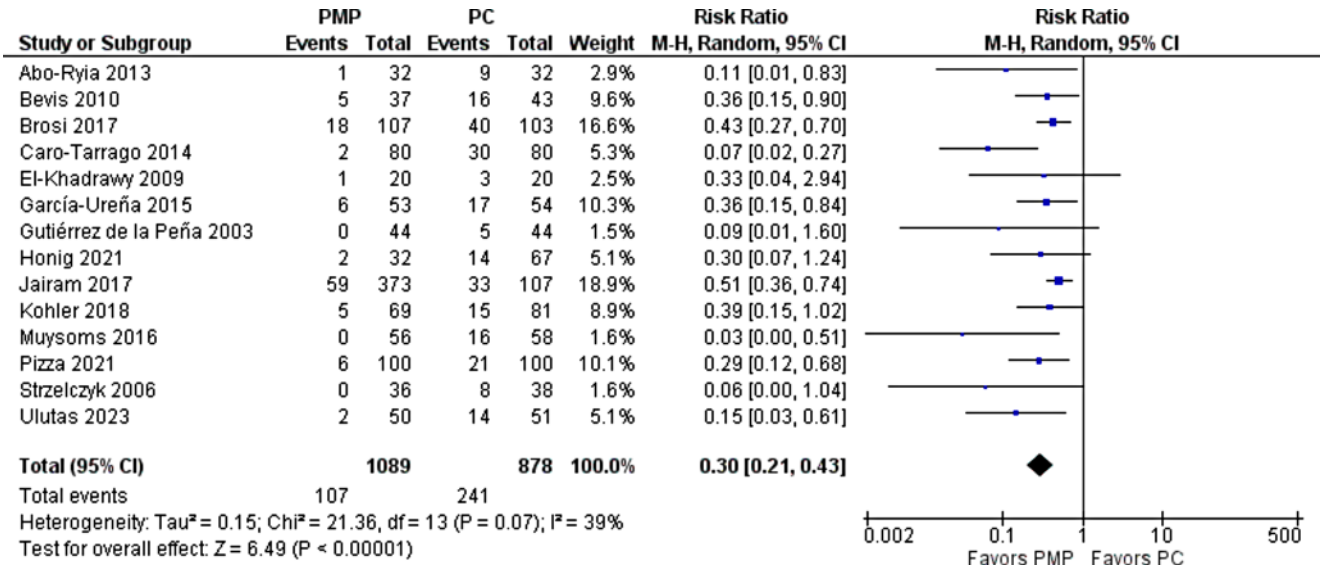

Fig. 2 The incidence of IH was significantly lower in Prophylactic Mesh group ($p < 0.01$). CI: Confidence Interval; PC: Primary Closure; PMP: Prophylactic Mesh Placement

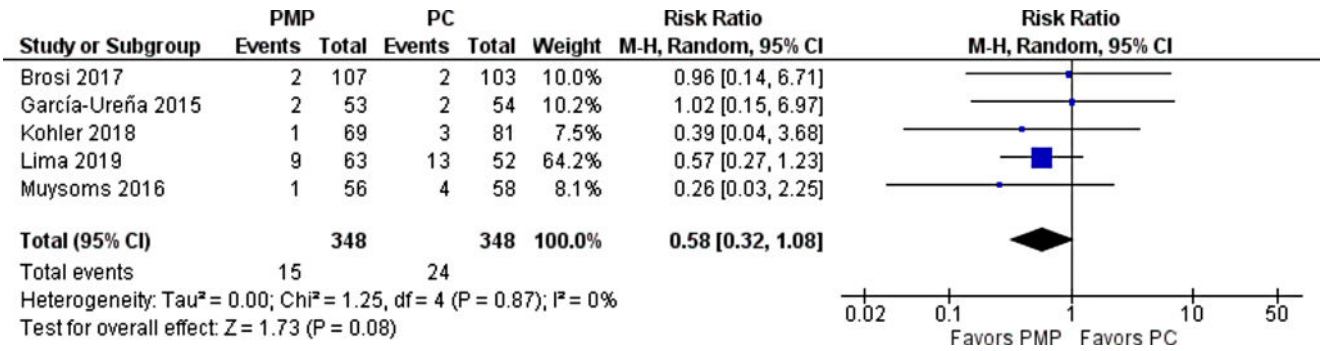

Fig. 3 The incidence of post-operative mortality was not significantly different in both groups ($p = 0.08$). CI: Confidence Interval; PC: Primary Closure; PMP: Prophylactic Mesh Placement

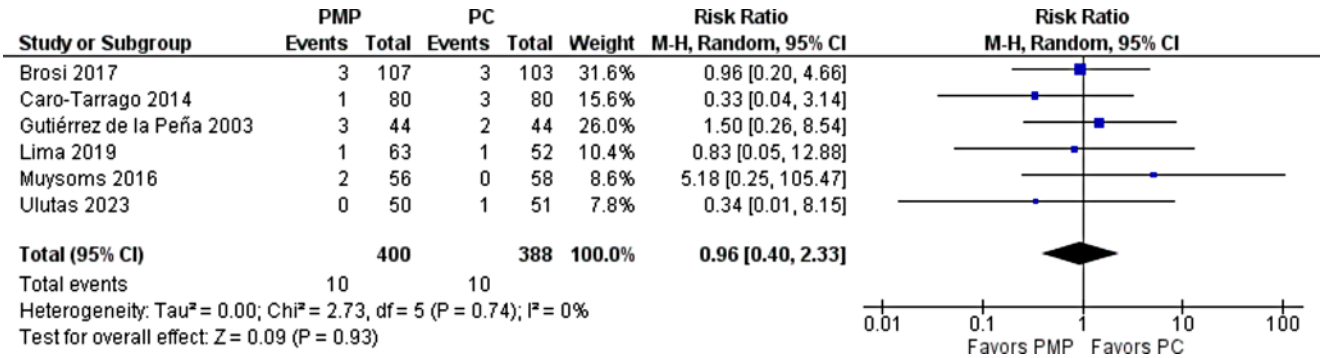

Fig. 4 The incidence of hematoma was not significantly different in both groups ($p = 0.93$). CI: Confidence Interval; PC: Primary Closure; PMP: Prophylactic Mesh Placement

was higher in PMP group (80/1046; 7,65%) when compared to PC group (39/806; 4,84%) and statistically different (RR 1.80; CI 95% 1.21–2.68; $p = 0.004$; $I^2 = 7\%$; Fig. 6).

Wound infection was showed in thirteen studies, five divided into superficial and deep wound infection, one reported only superficial infection [16], one only deep [22], one had no events in intervention or control group [27] and five did not specify the layer of infection [14, 15, 18, 20, 24]. The analysis was performed including all studies with events and them superficial and deep infection subgroups

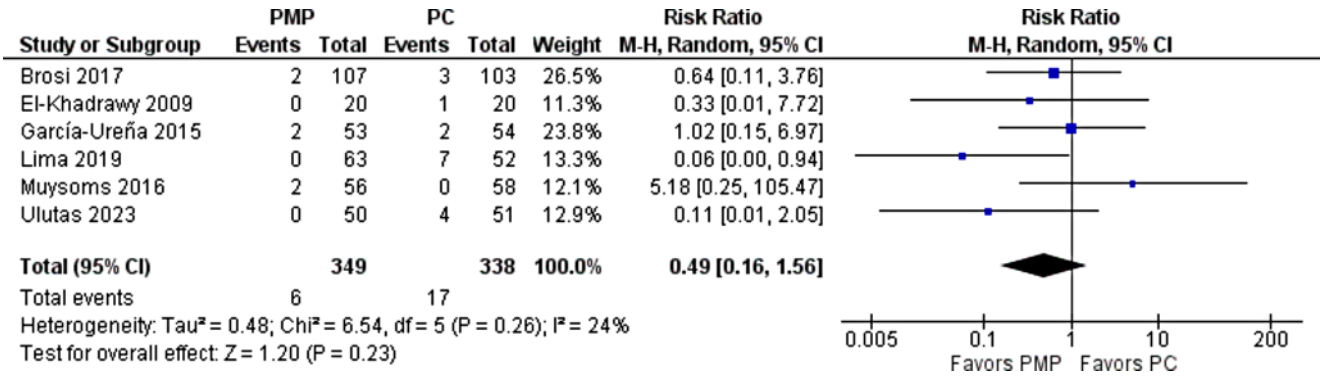

Fig. 5 The incidence of evisceration was not significantly in both groups ($p = 0.23$). CI: Confidence Interval; PC: Primary Closure; PMP: Prophylactic Mesh Placement

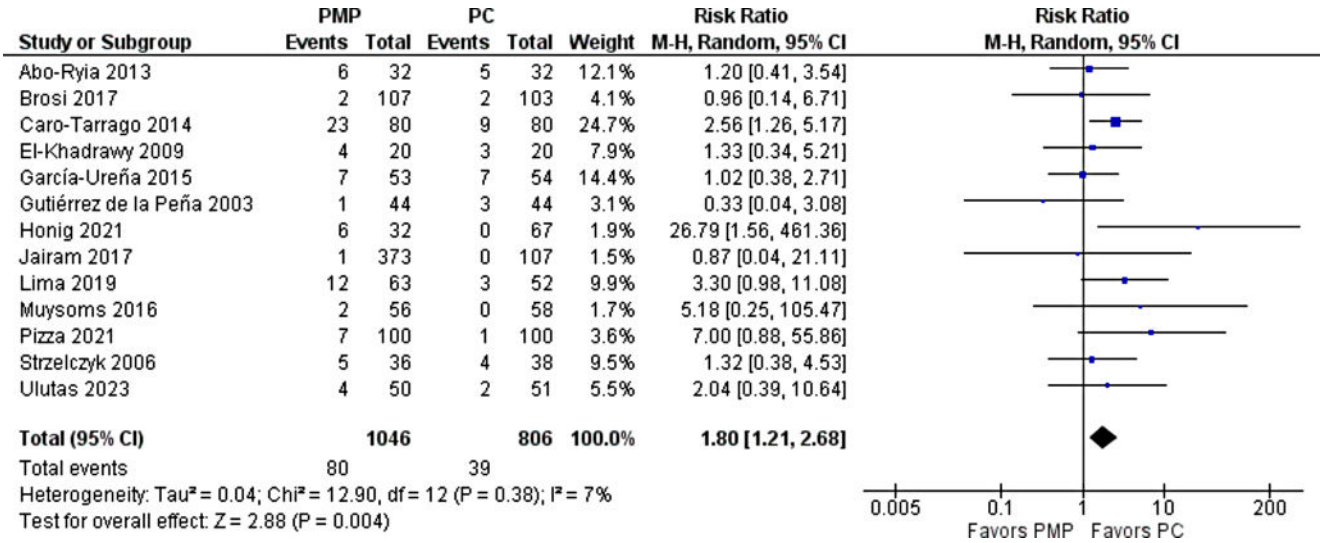

Fig. 6 The incidence of wound seroma was significantly lower in Primary Closure group ($p < 0.01$). CI: Confidence Interval; PC: Primary Closure; PMP: Prophylactic Mesh Placement

were analyzed. Wound infection had no statistical difference in both groups (RR 1.11; CI 95% 0.77–1.60; $p = 0.59$; I^2=0%; Fig. 7A) as well superficial (RR 1.02; CI 95% 0.60–1.72; $p = 0.95$; I^2=0%; Fig. 7B) and deep infection (RR 1.03; CI 95% 0.40–2.67; $p = 0.96$; I^2=0%; Fig. 7C).

Chronic Pain was reported in eight studies. In five of these studies, pain was defined according to Visual Analogue Scale (VAS), while in three, the number of patients experiencing pain was reported. VAS was assessed in different periods in each study, so we decided to standardize the data to pain reported between 12 and 24 months. During this period, one of the studies reported a zero VAS score in each group [28] and in one study it was not possible to assess the mean difference [16]. Therefore, data from three studies [22, 23, 26] were estimable, and no statistical difference between the groups was found (SMD −0.37; CI 95% -1.34-0.59; $p = 0.45$; I^2=97%; Fig. 8).

Eight studies had the data hospital length of stay. However, only six studies were analyzed, as two did not report the mean difference. Among the assessed studies, there was no significant difference between the groups (SMD −0.10; CI 95% -0.26-0.06; $p = 0.23$; I^2=0%; Fig. 9).

Subgroup analysis

A subgroup analysis by mesh location and the primary outcome was performed. However, the local of mesh placement was not associated with an increased risk of IH development, sublay (RR 0.29; CI 95% 0.15–0.57; $p = 0.0003$; I^2=51%), onlay (RR 0.25; CI 95% 0.13–0.47; $p < 0.0001$; I^2=48%) and IPOM (RR 0.42; CI 95% 0.27–0.65; $p = 0.0001$; I^2=0%) were associated with a significantly decreased rate of IH when compared to the PC group. The results are reported in Fig. 10.

The indication of surgery was also analyzed. In elective (RR 0.29; CI 95% 0.18–0.46; $p < 0.00001$; I^2=48%) and emergency (RR 0.24; CI 95% 0.11–0.50; $p = 0.0001$; I^2=0%) midline laparotomy, PMP had lower incidence of IH

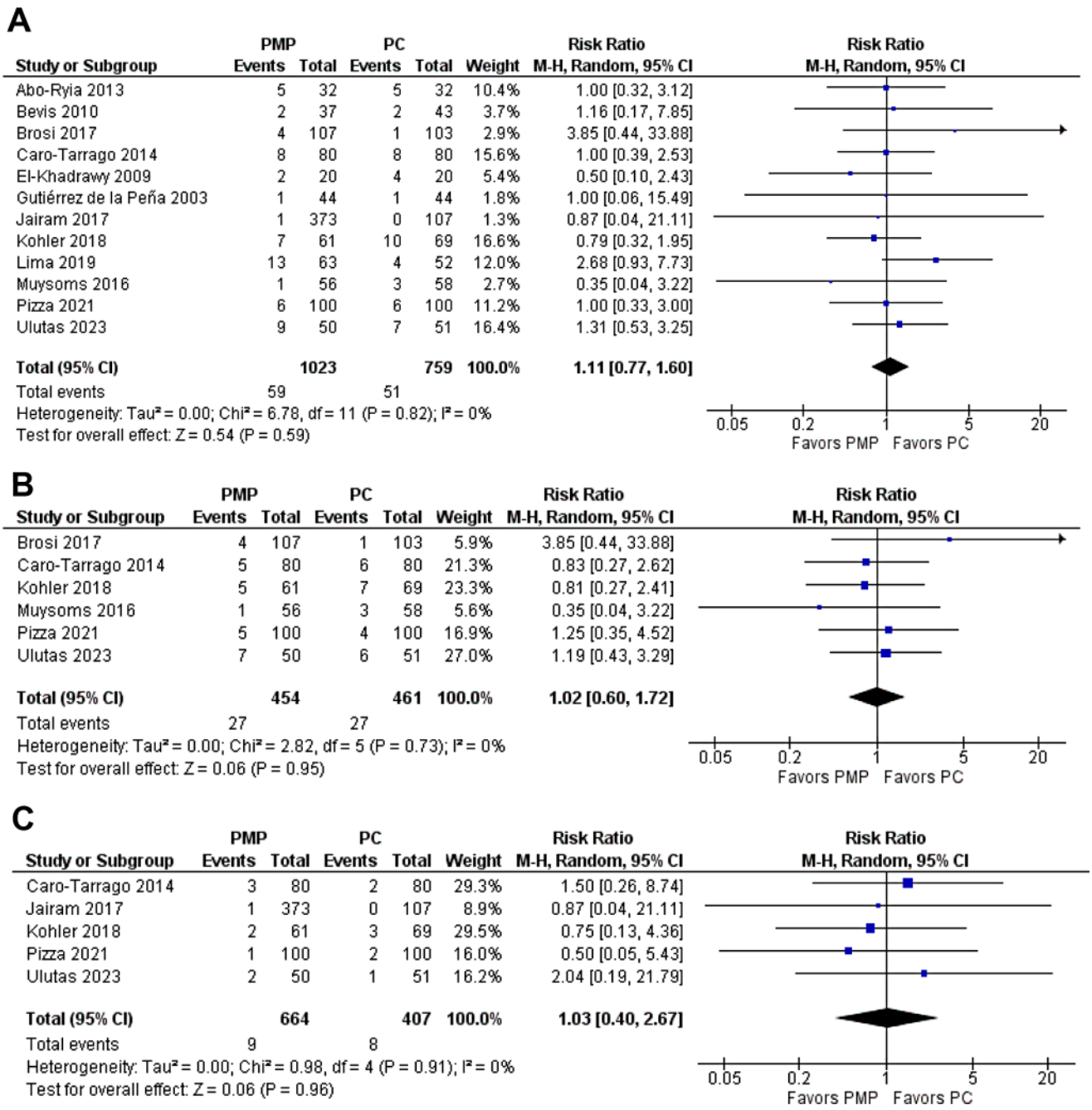

Fig. 7 (**A**) The incidence of wound infection was not significantly different in both groups ($p = 0.59$). (**B**) The incidence of superficial wound infection was not significantly different in both groups ($p = 0.95$). (**C**) The incidence of deep wound infection was not significantly different in both groups ($p = 0.96$). CI: Confidence Interval; PC: Primary Closure; PMP: Prophylactic Mesh Placement

when compared to PC (Fig. 11). It is important to highlight that García-Ureña et al. [19] included both in their study, nonetheless, the incidence of IH in each group of laparotomy indication was not informed, which is why we did not include the study in the analysis. Lima et al. [24] included only emergency laparotomies, but as cited before, this was the only study that did not present IH outcome.

The last subgroup included RCTs comparing permanent synthetic mesh to partial resorbable synthetic mesh. Since the resorbable material in the mesh used by Pizza et al. [26]. was limited to the microgrips for fixation, the study was categorized under the permanent synthetic mesh group for the subanalysis. The results still favored PMP in both permanent synthetic mesh (RR 0.28; 95% CI 0.17–0.43;

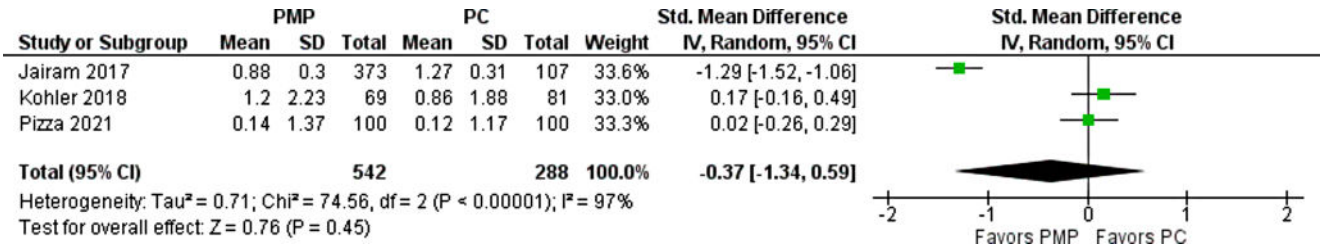

Fig. 8 Chronic pain was not significantly different in both groups ($p = 0.45$). CI: Confidence Interval; PC: Primary Closure; PMP: Prophylactic Mesh Placement

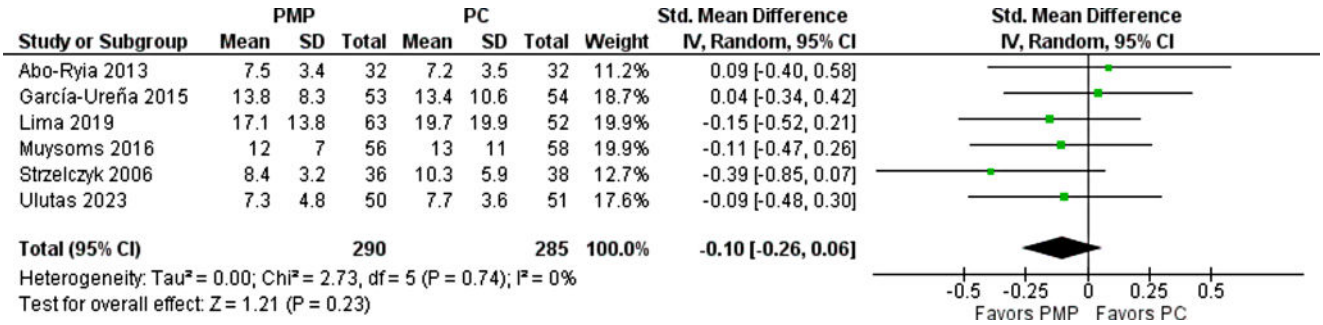

Fig. 9 The length of hospital stay was not significantly different in both groups ($p = 0.23$). CI: Confidence Interval; PC: Primary Closure; PMP: Prophylactic Mesh Placement

$p < 0.00001$; I^2=44%) and partial resorbable synthetic mesh (RR 0.31; 95% CI 0.11–0.85; $p = 0.02$; I^2=52%), Fig. 12.

Quality assessment

Patients and investigators were unblinded in five RCTs. Six trials were double blinded, Bevis et al. [15] blinded patients and surgeons until patient was anesthetized, Ulutas et al. [28] blinded patients and surgeons responsible for the analysis after the procedure was completed, four studies [21, 22, 25, 26] did not involve the operating surgeon in the follow-up, thus patients and physicians in charge of patient's care not involved in the operating room were blinded. A simple blind was performed in four studies [17, 19, 24, 27], two were unblinded [16, 23] and three did not give this information [14, 18, 20].

A visual Funnel plot analysis of the primary outcome showed an asymmetric distribution of studies (Fig. 13). Three studies got more distance from the others and their lower weight it is the possible explanation. The risk of bias is reported in Fig. 14.

Discussion

This systematic review and meta-analysis of 15 studies and 2,108 patients compared PMP of permanent synthetic and partial resorbable mesh vs. PC as strategies for patients undergoing midline laparotomy. The main findings from the pooled analysis were: (1) the significantly lower incidence of IH in the PMP group, with this result also applicable to subgroup analysis including mesh position (onlay, sublay or IPOM) and surgery indication (elective or emergency); (2) a lower incidence of seroma, which was the only outcome that favored the PC group; and (3) no statistically significant difference between the groups for the other secondary outcomes analyzed (post-operative complications and period of hospitalization).

The main outcome of this study had similar results compared to previous meta-analysis that included absorbable mesh and observational studies, reinforcing that prophylactic mesh placement in laparotomy closure reduces the incidence of IH [7–10], and regarding the use of prophylactic bio-absorbable mesh, previous RCTs have yielded inconsistent results of its benefits [29–31]. More recent meta-analyses support similar findings, however, it is important to emphasize key differences in the included studies and the statistical analyses applied in our study.

The study by Marcolin et al. [32]. included a subgroup analysis of synthetic mesh placement; however, it was limited to emergency laparotomies, not addressing the effects of synthetic mesh in elective laparotomies. Similarly, Aiolfi et al. [33]. included nearly the same number of studies as we did, but including only elective laparotomies, leading to the exclusion of at least two studies involving 301 patients who underwent emergency laparotomies. In contrast, our study included both emergency and elective cases and performed subgroup analyses to assess the effect of different surgical

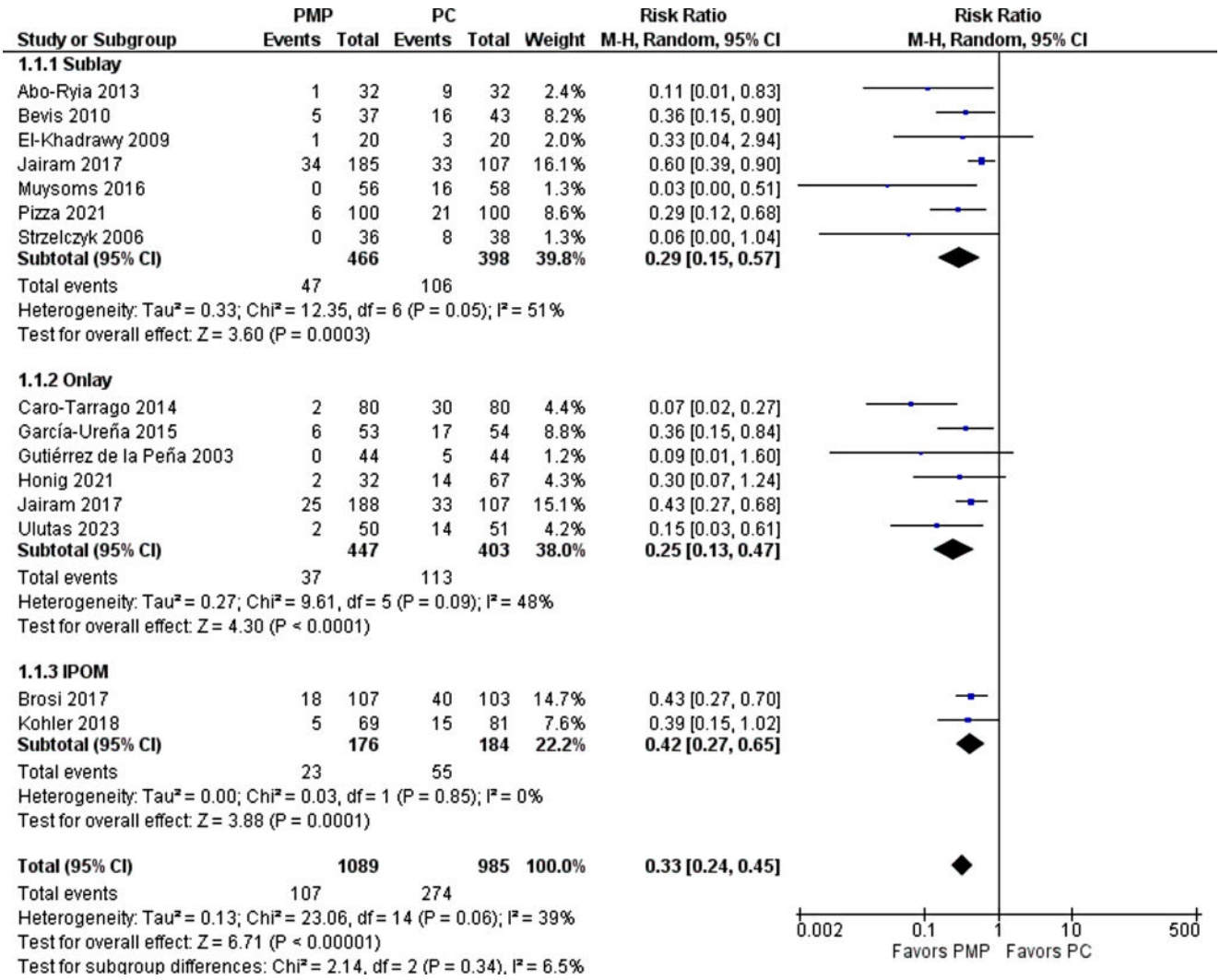

Fig. 10 There is no difference between different mesh position. CI: Confidence Interval; PC: Primary Closure; PMP: Prophylactic Mesh Placement

techniques on our primary outcome. Furthermore, Aiolfi et al. did not restrict their analysis by mesh type, and while they included ten studies with permanent mesh, our analysis includes fifteen studies, all exclusively using permanent mesh.

Additionally, Frassini et al..'s [34] study included both emergency and elective cases but did not restrict the analysis to a specific type of mesh, incorporating both absorbable and permanent synthetic meshes. Despite this, their meta-analysis demonstrated significant heterogeneity between studies and no subgroup analysis by mesh type was conducted, although a sensitive analysis was performed. Nonetheless, the authors acknowledged that the choice of mesh type and surgical technique remains an unresolved issue and suggested future research should focus on this, particularly in emergency settings. Our meta-analysis addresses this gap by focusing on permanent synthetic mesh types and providing comprehensive subgroup analyses that consider surgical techniques, mesh positions, and mesh types to better understand the effects of permanent synthetic mesh placement.

The use of mesh it is a well-known creator of tissue response [35], which justifies the higher incidence of seroma in the PMP group. Nevertheless, this did not affect length of hospital stay in the majority of studies, nor did it require complex interventions. Additionally, our pooled analysis of length of hospital stay showed no difference between groups.

One of the major concerns related to the use of prophylactic synthetic mesh is regarding the risk of infection, particularly in emergency surgeries and potentially contaminated surgery [19, 26, 28]. This concern arises because permanent synthetic material could theoretically increase the risk and the duration of infection. However, previous studies, including a meta-analysis [36, 37], have shown a significantly higher risk of surgical site infection with absorbable mesh compared to permanent synthetic mesh in ventral hernia

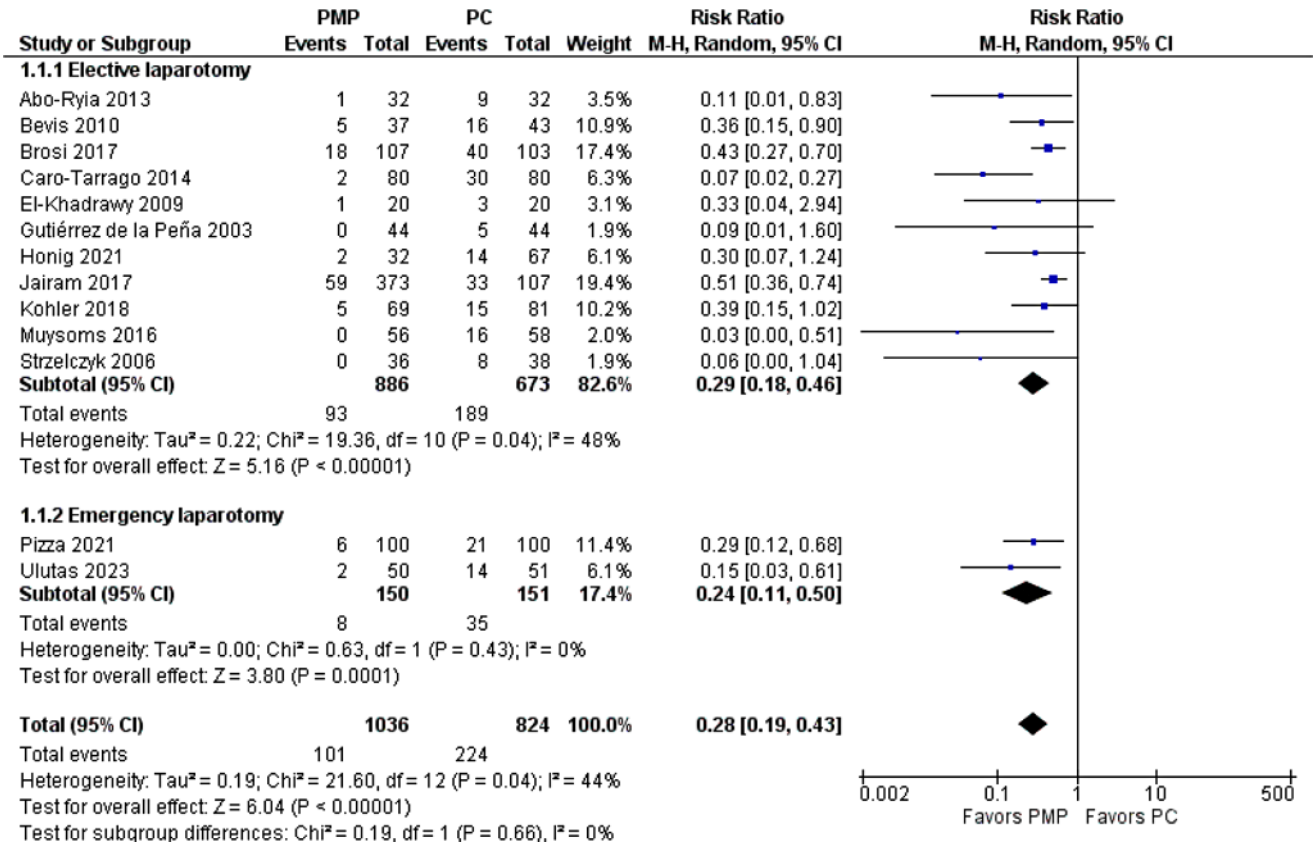

Fig. 11 There is no difference between different laparotomy indication. CI: Confidence Interval; PC: Primary Closure; PMP: Prophylactic Mesh Placement

repair. Our included studies did not demonstrate an increase in wound infection with permanent synthetic or partial resorbable mesh use, which is further supported by the present pooled analysis. Moreover, most of the studies reporting wound infection following mesh placement did not require surgical reintervention and did not increase the LOS. Only one study [25] reported the necessity of mesh removal due to a deep infection.

In the subgroup analysis, we found that sublay, onlay and IPOM had a similarly positive effect in IH incidence. However, literature suggests that onlay and sublay positions may be more effective than IPOM. The long-term outcomes from Jairam et al. [22]. demonstrated a significant reduction in IH incidence over five years with sublay and onlay mesh placement [38]. This finding is further supported by the five-year follow-up from Muysoms et al. [25], which reported no IHs diagnosed in the mesh group, while the cumulative incidence of IH in the PC group reached 49.2% [39]. The IPOM technique carries a theoretical risk of bowel wall erosion in direct contact with the mesh, but this risk is not reported in the literature. None of our included studies reported this complication, even in those using IPOM with permanent synthetic mesh [14–25, 27]. The onlay repair is usually simple and easy to perform without a significant increase in operative time [31, 40]. However, in our pooled analysis, it was more associated with seroma formation than sublay and PC.

The European and American Societies [12] recommend that the use of prophylactic mesh augmentation after elective midline laparotomy can be considered, and they recommend using a permanent synthetic mesh. However, the quality of evidence is very low, since there are no studies comparing different types of mesh for prophylactic mesh placement. The present meta-analysis contributes to recent data suggesting that a permanent mesh, whether partial resorbable or not, reduces the incidence of IH compared to PC. Considering the low cost and the widespread availability of synthetic mesh materials, this strategy can be implemented in many hospitals worldwide.

Nonetheless, this study has some limitations. Most importantly, four studies used a partial resorbable synthetic mesh, wherein one only the microgrips for fixation were resorbable. To mitigate the potential impact of differential baseline characteristics between interventions, we conducted a subgroup analysis comparing permanent synthetic materials to partial resorbable synthetic materials, which consistently showed a reduction in IH incidence. Additionally, the majority of included studies focused on high-risk patients

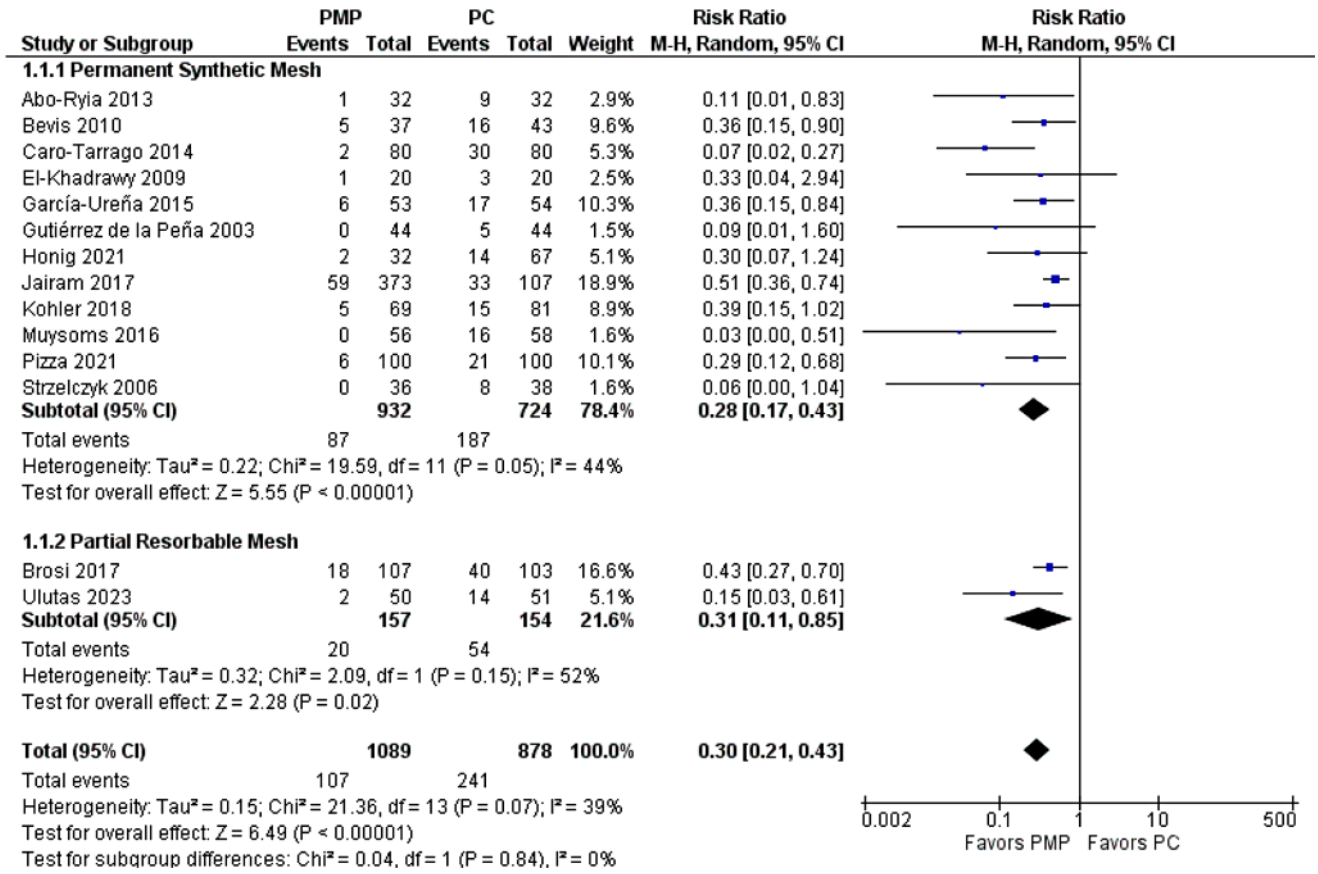

Fig. 12 Subgroup analysis of permanent synthetic mesh vs. partial resorbable synthetic mesh. CI: Confidence Interval; PC: Primary Closure; PMP: Prophylactic Mesh Placement

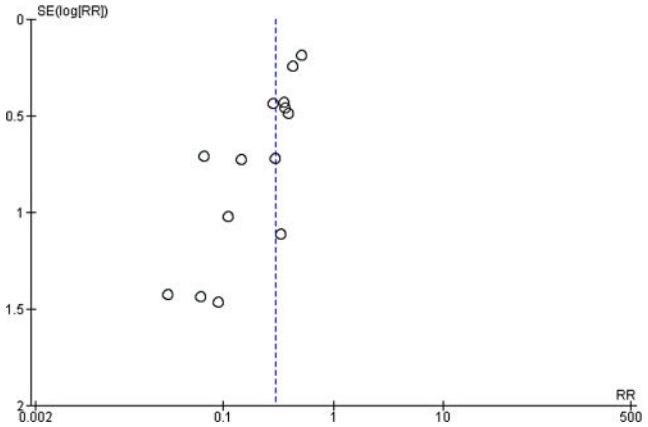

Fig. 13 Funnel plot analysis showing an assimetric distribution of included studies

for IH formation, which may affect our results when compared to studies involving low-risk patients for IH.

Another limitation is that in most studies, mesh placement was not performed by a hernia specialist, nor was the mesh placement technique standardized across the surgeries. Additionally, the technique of abdominal wall closure was not either standardized among the studies; only a few studies used small bites technique and a wound length rate of 4:1 using delayed absorbable sutures in both the intervention and PC groups [21, 23]. This lack of standardization could contribute to the relatively high heterogeneity observed in our findings related to IH incidence.

In future clinical trials, guideline-recommended techniques should be followed to reduce bias and ensure a more uniform population. It would also be beneficial to have an experienced abdominal wall specialist performing the closures. Additionally, there is no consensus on defining high-risk patients for hernia formation, so future studies should establish a clear definition, possibly using a scoring system, and including subgroup analyses of different risk patients. Finally, direct comparisons between absorbable and permanent synthetic mesh types in clinical trials would provide valuable insights.

Conclusion

This meta-analysis including 2,108 patients highlights the superior postoperative results of the PMP group in patients undergoing laparotomy. The incidence of IH was

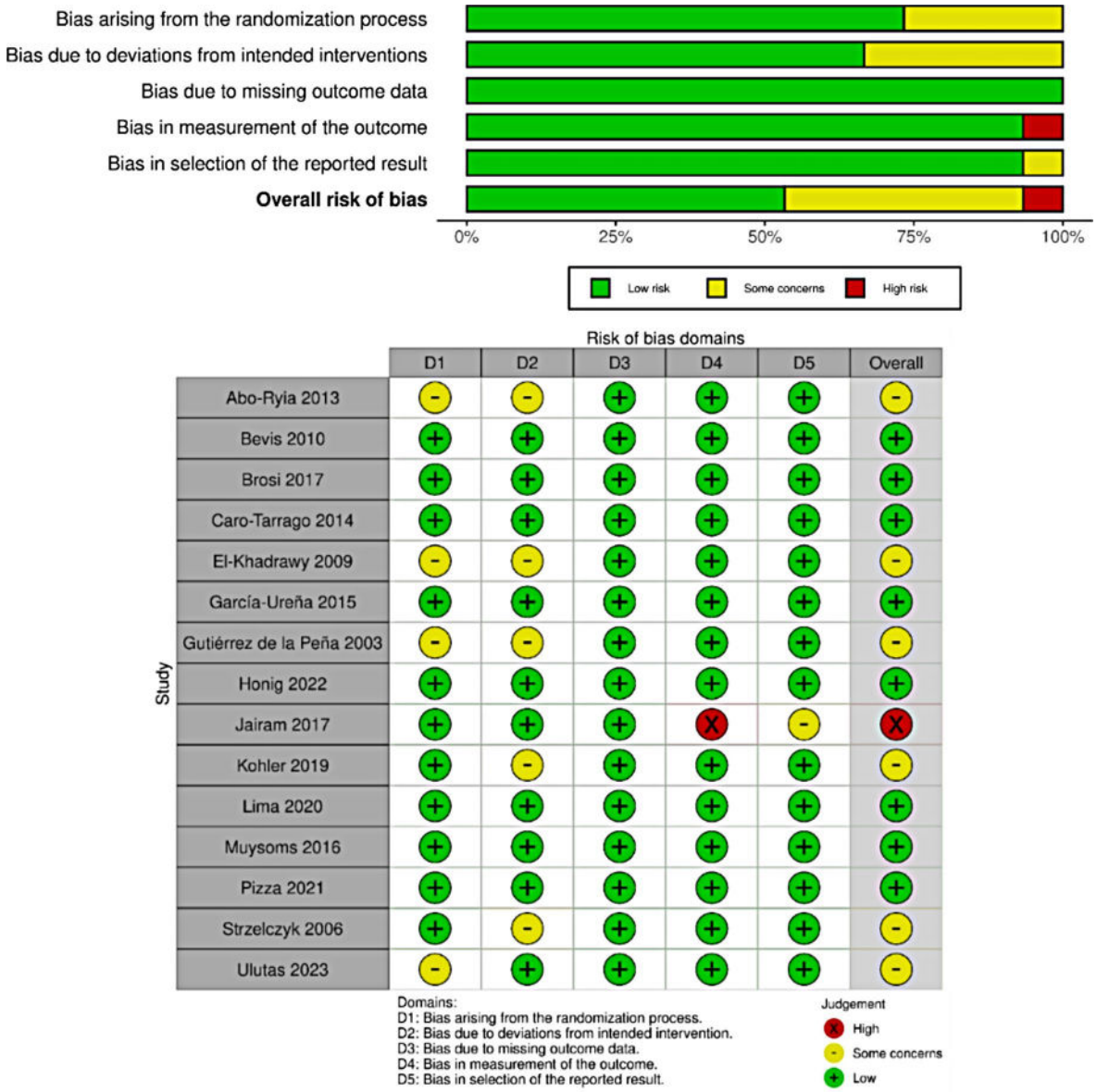

Fig. 14 Risk of bias assessment

significantly lower with PMP compared to PC. Moreover, secondary outcomes analyzed related to post-operative complications and duration of hospitalization did not show statistically significant differences, except for seroma, which favored the PC group. Therefore, these findings indicate that the PMP demonstrates superiority in reducing postoperative complication rates compared to PC for laparotomy closure.

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Declarations

Conflict of interest The authors Ana Paula Valério-Alves, Caio Leonardo dos Santos Saggin, João Marcos Escórcio de Aguiar Portela, Patricia Viana, Gabriela Branquinho Guerra, Camila Mariana de Paiva Reis and Rafael Morriello, declare they have no conflict of interest.

References

1. Bosanquet DC, Ansell J, Abdelrahman T, Cornish J, Harries R, Stimpson A et al (2015) Systematic review and meta-regression of factors affecting midline incisional hernia rates: analysis of 14,618 patients. PLoS ONE 10. https://doi.org/10.1371/journal.pone.0138745
2. Hoffman RD, Danos DM, Lau FH (2021) National health disparities in incisional hernia repair outcomes: an analysis of the Healthcare Cost and Utilization Project National Inpatient Sample (HCUP-NIS) 2012–2014. Surgery 169(6):1393–1399. https://doi.org/10.1016/j.surg.2020.11.028
3. Omar I, Townsend A, Hadfield O, Zaimis T, Ismaiel M, Wilson J et al (2024) Outcomes of elective and emergency surgical repair

of incisional hernia: a comparative observational study. Hernia. https://doi.org/10.1007/s10029-024-02975-4
4. Seiler CM, Bruckner T, Diener MK, Papyan A, Golcher H, Seidlmayer C et al (2009) Interrupted or continuous slowly absorbable sutures for closure of primary elective midline abdominal incisions: a multicenter randomized trial (INSECT: ISRCTN24023541). Ann Surg 249(4):576–582. https://doi.org/10.1097/SLA.0b013e31819ec6c8
5. Omar I, Anany A, Ismaiel M et al (2024) Outcomes of surgical repair of incisional hernia in patients with severe and morbid obesity: a comparative study. Cureus 16(3). https://doi.org/10.7759/cureus.55782
6. Onyekaba G, Mauch JT, Patel V et al (2022) The abdominal Hernia-Q: a critical analysis of the components that impact quality-of-life. Hernia 26:839–846. https://doi.org/10.1007/s10029-022-02640-1
7. Payne R, Aldwinckle J, Ward S (2017) Meta-analysis of randomised trials comparing the use of prophylactic mesh to standard midline closure in the reduction of incisional herniae. Hernia 21:843–853. https://doi.org/10.1007/s10029-017-1661-7
8. Ahmed J, Hasnain N, Fatima I, Malik F, Chaudhary MA, Ahmad J et al (2020) Prophylactic mesh placement for the prevention of incisional hernia in high-risk patients after abdominal surgery: a systematic review and meta-analysis. Cureus 12. https://doi.org/10.7759/cureus.10491
9. Hassan MA, Yunus RM, Khan S, Memon MA (2021) Prophylactic onlay mesh repair (POMR) versus primary suture repair (PSR) for prevention of incisional hernia (IH) after abdominal wall surgery: a systematic review and meta-analysis. World J Surg 45:3080–3091. https://doi.org/10.1007/s00268-021-06124-6
10. Indrakusuma R, Jalalzadeh H, van der Meij JE, Balm R, Koelemay MJW (2018) Prophylactic mesh reinforcement versus sutured closure to prevent incisional hernias after open abdominal aortic aneurysm repair via midline laparotomy: a systematic review and meta-analysis. Eur J Vasc Endovasc Surg 56:120–128. https://doi.org/10.1016/j.ejvs.2018.03.017
11. Depuydt M, Allaeys M, de Carvalho LA, Vanlander A, Berrevoet F (2021) Prophylactic mesh after midline laparotomy: evidence is out there, but why do surgeons hesitate? World J Surg 45(5):1349–1361. https://doi.org/10.1007/s00268-021-06064-1
12. Deerenberg EB, Henriksen NA, Antoniou GA, Antoniou SA, Bramer WM, Fischer JP et al (2022) Updated guideline for closure of abdominal wall incisions from the European and American Hernia societies. Br J Surg 109(12):1239–1250. https://doi.org/10.1093/bjs/znac291
13. Diab MM, Patel S, Young C, Allen IE, Harris HW (2024) Quality of life measures and cost analysis of biologic versus synthetic mesh for ventral hernia repair: the preventing recurrence in clean and contaminated hernias randomized clinical trial. Surgery 175(4):1063–1070. https://doi.org/10.1016/j.surg.2023.12.002
14. Abo-Ryia MH, El-Khadrawy OH, Abd-Allah HS (2013) Prophylactic preperitoneal mesh placement in open bariatric surgery: a guard against incisional hernia development. Obes Surg 23(10):1571–1574. https://doi.org/10.1007/s11695-013-0972-6
15. Bevis PM, Windhaber RA, Lear PA, Poskitt KR, Earnshaw JJ, Mitchell DC (2010) Randomized clinical trial of mesh versus sutured wound closure after open abdominal aortic aneurysm surgery. Br J Surg 97(10):1497–1502. https://doi.org/10.1002/bjs.7158
16. Brosi P, Glauser PM, Speich B, Käser SA, Maurer CA (2018) Prophylactic intraperitoneal onlay mesh reinforcement reduces the risk of incisional hernia: two-year results of a randomized clinical trial. World J Surg 42(6):1687–1694. https://doi.org/10.1007/s00268-018-4522-1
17. Caro-Tarrago A, Olona Casas C, Jimenez Salido A, Duque Guilera E, Moreno Fernandez F, Vicente Guillen V (2014) Prevention of incisional hernia in midline laparotomy with an onlay mesh: a randomized clinical trial. World J Surg 38(9):2223–2230. https://doi.org/10.1007/s00268-014-2567-z
18. El-Khadrawy OH, Moussa G, Mansour O, Hashish MS (2009) Prophylactic prosthetic reinforcement of midline abdominal incisions in high-risk patients. Hernia 13(3):267–274. https://doi.org/10.1007/s10029-009-0481-4
19. García-Ureña MÁ, López-Monclús J, Hernando LA, Montes DM, Valle de Lersundi AR, Pavón CC et al (2015) Randomized controlled trial of the use of a large-pore polypropylene mesh to prevent incisional hernia in colorectal surgery. Ann Surg 261(5):876–881. https://doi.org/10.1097/SLA.0000000000000971
20. de la Gutiérrez C, Medina Achirica C, Domínguez-Adame E, Medina Díez J (2003) Primary closure of laparotomies with high risk of incisional hernia using prosthetic material: analysis of usefulness. Hernia 7(3):134–136. https://doi.org/10.1007/s10029-003-0124-2
21. Honig S, Diener H, Kölbel T, Reinpold W, Zapf A, Bibiza-Freiwald E et al (2022) Abdominal incision defect following AAA-surgery (AIDA): 2-year results of prophylactic onlay-mesh augmentation in a multicentre, double-blind, randomised controlled trial. Updates Surg 74(3):1105–1116. https://doi.org/10.1007/s13304-021-01049-y
22. Jairam AP, Timmermans L, Eker HH, Pierik REGJM, van Klaveren D, Steyerberg EW et al (2017) Prevention of incisional hernia with prophylactic onlay and sublay mesh reinforcement versus primary suture only in midline laparotomies (PRIMA): 2-year follow-up of a multicentre, double-blind, randomised controlled trial. Lancet 390(10094):567–576. https://doi.org/10.1016/S0140-6736(17)31137-6
23. Kohler A, Lavanchy JL, Lenoir U, Kurmann A, Candinas D, Beldi G (2019) Effectiveness of prophylactic intraperitoneal mesh implantation for prevention of incisional hernia in patients undergoing open abdominal surgery: a randomized clinical trial. JAMA Surg 154(2):109–115. https://doi.org/10.1001/jamasurg.2018.5090
24. Lima HV, Rasslan R, Novo FC, Lima TM, Damous SH, Bernini CO et al (2020) Prevention of fascial dehiscence with onlay prophylactic mesh in emergency laparotomy: a randomized clinical trial. J Am Coll Surg 230(1):76–87. https://doi.org/10.1016/j.jamcollsurg.2019.09.012
25. Muysoms FE, Detry O, Vierendeels T, Huyghe M, Miserez M, Ruppert M et al (2016) Prevention of incisional hernias by prophylactic mesh-augmented reinforcement of midline laparotomies for abdominal aortic aneurysm treatment: a randomized controlled trial. Ann Surg 263(4):638–645. https://doi.org/10.1097/SLA.0000000000001466
26. Pizza F, D'Antonio D, Ronchi A, Lucido FS, Brusciano L, Marvaso A et al (2021) Prophylactic sublay non-absorbable mesh positioning following midline laparotomy in a clean-contaminated field: randomized clinical trial (PROMETHEUS). Br J Surg 108(6):638–643. https://doi.org/10.1093/bjs/znab125
27. Strzelczyk JM, Szymański D, Nowicki ME, Wilczyński W, Gaszynski T, Czupryniak L (2006) Randomized clinical trial of postoperative hernia prophylaxis in open bariatric surgery. Br J Surg 93(11):1347–1350. https://doi.org/10.1002/bjs.5516
28. Ulutas ME, Sahin A, Simsek G, Sekmenli N, Kilinc A, Arslan K et al (2023) Does onlay mesh placement in emergency laparotomy prevent incisional hernia? A prospective randomized double-blind study. Hernia 27(4):883–893. https://doi.org/10.1007/s10029-023-02787-y
29. Sarr MG, Hutcher NE, Snyder S, Hodde J, Carmody B (2014) A prospective, randomized, multicenter trial of Surgisis Gold, a biologic prosthetic, as a sublay reinforcement of the fascial closure after open bariatric surgery. Surgery 156(4):902–908. https://doi.org/10.1016/j.surg.2014.07.004

30. Bali C, Papakostas J, Georgiou G, Kouvelos G, Avgos S, Arnaoutoglou E et al (2015) A comparative study of sutured versus bovine pericardium mesh abdominal closure after open abdominal aortic aneurysm repair. Hernia 19(2):267–271. https://doi.org/10.1007/s10029-014-1260-7
31. Muysoms FE, Jairam A, Lopez-Cano M, Smietanski M, Woeste G, Kyle-Leinhase I et al (2016) Prevention of incisional hernias with biological mesh: a systematic review of the literature. Front Surg 3:53. https://doi.org/10.3389%2Ffsurg.2016.00053
32. Marcolin P, Mazzola Poli de Figueiredo S, Oliveira Trindade B, Bueno Motter S, Brandão GR, Mao RD, Moffett JM (2024) Prophylactic mesh augmentation in emergency laparotomy closure: a meta-analysis of randomized controlled trials with trial sequential analysis. Hernia 28(3):677–690. https://doi.org/10.1007/s10029-023-02943-4
33. Aiolfi A, Cavalli M, Gambero F, Mini E, Lombardo F, Gordini L et al (2023) Prophylactic mesh reinforcement for midline incisional hernia prevention: systematic review and updated meta-analysis of randomized controlled trials. Hernia 27(2):213–224. https://doi.org/10.1007/s10029-022-02660-4
34. Frassini S, Calabretto F, Granieri S, Fugazzola P, Massaro M, Sargenti B et al (2023) Prophylactic mesh augmentation after laparotomy for elective and emergency surgery: meta-analysis. BJS Open 7(4). https://doi.org/10.1093/bjsopen/zrad060
35. Paulo NM, Malmonge SM, Menezes LB, Lima FG, Faria Ade M, Andrasckho MM et al (2010) Evaluation of peritoneal adhesions formation and tissue response to polypropylene - poli (2-hydroxyethyl methacrylate)-(polyHEMA) implant on rats' abdominal wall. Acta Cir Bras 25(4):337–341. https://doi.org/10.1590/S0102-86502010000400007
36. Warren J, Desai SS, Boswell ND, Hancock BH, Abbad H, Ewing JA et al (2020) Safety and efficacy of synthetic mesh for ventral hernia repair in a contaminated field. J Am Coll Surg 230(4):405–413. https://doi.org/10.1016/j.jamcollsurg.2019.12.008
37. Morris MP, Mellia JA, Christopher AN et al (2021) Ventral hernia repair with synthetic mesh in a contaminated field: a systematic review and meta-analysis. Hernia 25:1035–1050. https://doi.org/10.1007/s10029-020-02358-5
38. Van den Dop LM, Sneiders D, Yurtkap Y, Werba A, van Klaveren D, Pierik REGJM et al (2023) Prevention of incisional hernia with prophylactic onlay and sublay mesh reinforcement vs. primary suture only in midline laparotomies (PRIMA): long-term outcomes of a multicentre, double-blind, randomised controlled trial. Lancet Reg Health Eur 36:100787. https://doi.org/10.1016/j.lanepe.2023.100787
39. Dewulf M, Muysoms F, Vierendeels T, Huyghe M, Miserez M, Ruppert M et al (2022) Prevention of incisional hernias by prophylactic mesh-augmented reinforcement of midline laparotomies for abdominal aortic aneurysm treatment: five-year follow-up of a randomized controlled trial. Ann Surg 276(4). https://doi.org/10.1097/SLA.0000000000005545
40. Tansawet A, Numthavaj P, Techapongsatorn S, Wilasrusmee C, Attia J, Thakkinstian A (2020) Mesh position for hernia prophylaxis after midline laparotomy: a systematic review and network meta-analysis of randomized clinical trials. Int J Surg 83:144–151. https://doi.org/10.1016/j.ijsu.2020.08.059

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