A Comprehensive, Evidence-Based Literature Review of the Surgical Treatment of Rectus Diastasis

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Background: Rectus diastasis is a common condition that can result in a protruding abdomen, causing cosmetic and functional disability. Although it is usually repaired during abdominoplasty or herniorrhaphy, there is a lack of consensus with regard to the repair indications and optimal surgical techniques. The goal of this study is to provide an updated review of the surgical techniques used for rectus diastasis repair and their comparative efficacy.
Methods: In accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines, the PubMed, Embase, and Cochrane databases were searched for articles that discussed the surgical management of rectus diastasis and reported on either outcomes, complications, or recurrence rates. Data detailing surgical techniques were extracted, and pooled analyses of complication and recurrence rates were performed, controlling for surgical approach, common variations in technique, and an associated herniorrhaphy.
Results: Thirty-seven studies describing 45 techniques were included. An open rectus diastasis repair was performed in 24 of the studies. After controlling for an associated herniorrhaphy, there was no statistically significant difference in surgical complication and recurrence rates between open and laparoscopic approaches (p = 0.165 and p = 0.133, respectively). Although a double-layer suture closure was associated with a significantly lower rate of complications (p = 0.002), no significant difference was found for suture type absorbability.
Conclusions: Surgical repair of rectus diastasis is safe and effective through both open and laparoscopic approaches. Although suture type absorbability does not affect complication or recurrence rates, a double-layer suture closure can decrease surgical complications. The pooled analysis of complication and recurrence rates can help improve informed consent and patient education. (*Plast. Reconstr. Surg.* 146: 1151, 2020.)

Defined as widening of the linea alba along its length and separation of the rectus abdominis muscles at midline, abdominal rectus diastasis is a common condition encountered by both plastic and general surgeons.[1] Rectus diastasis is a result of laxity of the abdominal aponeurosis,[1] usually caused by increased intra-abdominal pressure from pregnancy,[2] obesity, or advanced age.[3] Although a separation of the rectus muscles of more than 2 cm is commonly considered pathologic, there is a lack of consensus on what constitutes a normal linea alba, and thus what is a true diagnosis of rectus diastasis.[4,5] To further complicate the diagnosis, the physiologic interrectus distance varies along the length of the abdominal midline. A recent review by the International Endohernia Society proposed classifying rectus diastasis according to its location along the

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Received for publication October 8, 2019; accepted May 8, 2020.

DOI: 10.1097/PRS.0000000000007252

Disclosure: *Dr. Janis receives royalties from Thieme Publishing. The other authors have no financial disclosures to report. No funding was received for this article.*

Related digital media are available in the full-text version of the article on www.PRSJournal.com.

midline: subxiphoid, epigastric, umbilical, infraumbilical, or suprapubic.[6] They propose classifying rectus diastasis according to its size: a width of less than 3 cm is mild, 3 to 5 cm is moderate, and more than 5 cm is severe.[6] Although not a true hernia, rectus diastasis is clinically associated with a protruding abdomen, which may conceal a ventral hernia. The paucity of data regarding the repair of rectus diastasis and its functional sequelae is evident by its classification in the CPT coding as a solely cosmetic procedure and therefore not covered by the vast majority of insurance plans in the United States.[7]

Rectus diastasis results in the loss of integrity of the intraabdominal wall, causing aesthetic dissatisfaction, functional impairment, and musculoskeletal pain. Furthermore, it can cause abdominal protrusion, which has been linked to weakness and instability of the trunk and the pelvic muscles, and increases spine and pelvic vulnerability to injury.[8] Moreover, rectus diastasis has been shown to strongly correlate with an overall negative body image.[9] When left untreated, rectus diastasis is often a permanent deformity associated with an increased risk of developing a midline hernia.[6,10]

Current treatment methods of rectus diastasis vary on a wide spectrum ranging from conservative physiotherapy to surgical procedures, with varying degrees of invasiveness.[8,11] There are currently no guidelines dictating when rectus diastasis should be repaired; however, treatment is commonly performed at the same time as abdominoplasty and hernia repair to improve function and aesthetic result.[12,13] With the rapid development of open and minimally invasive rectus diastasis repair techniques, the evidence is lacking with regard to their comparative efficacy, complication profile, and recurrence rates. As such, it is difficult for both surgeons and patients to make evidence-based and informed decisions with regard to repair options.

In this review, the authors aim to provide an updated report on the current state of rectus diastasis surgical repair. The primary goals of this article are to present a comprehensive overview of all surgical rectus diastasis repair techniques, and to compare complication profiles and recurrence rates of open and laparoscopic approaches. The secondary goals of this study are to provide accurate pooled analyses of complication and recurrence rates for different repair techniques and compare variables such as suture absorbability and layer closure (single- or double-layer repair).

PATIENTS AND METHODS

Search Strategy

A systematic search of the National Library of Medicine (PubMed), Embase, and Cochrane Library databases was conducted to retrieve all available literature regarding rectus diastasis surgical management techniques. The search strategy used in PubMed was the following: (divarication OR diastasis OR plication) AND (recti OR rectus OR abdomen OR abdominal OR abdominis). The other databases were searched by means of similar search strategies.

In compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses, two independent authors reviewed each search result against the inclusion and exclusion criteria. After removal of duplicates, the articles were first screened using titles and abstracts. The remaining articles underwent a full-text review. Any discrepancies between the two reviewers were resolved through discussion and consensus. Included were articles in English that discussed the surgical management of rectus diastasis and reported on either outcomes, complications, or recurrence rates. Excluded were articles that grouped patients with and without rectus diastasis, without performing a subanalysis of outcomes or complication/recurrence rates. Articles with fewer than seven cases were excluded. Finally, animal, cadaver, and biomechanical studies were excluded.

Data Collection and Quantitative Synthesis

Data extracted from each article included type of study, surgical approach (open and/or minimally invasive), rectus diastasis repair technique, associated ventral hernia repair, use of mesh reinforcement, patient population, repair outcomes, complications, and diastasis recurrence rates. Pooled analyses of complication and recurrence rates were performed to compare open and minimally invasive rectus diastasis repairs. Furthermore, for each surgical method (open or minimally invasive), the data were further stratified based on the presence of a hernia repair, the absorbability of sutures used (i.e., short-acting absorbable, long-acting absorbable, or nonabsorbable), and finally whether the recti were repaired by means of a single- or a double-layer suture closure of the abdominal fascia. To avoid overestimating/underestimating complication and recurrence rates, any study that did not explicitly report on these variables was excluded from the pooled analyses. Chi-square and Fisher's

exact tests were used to assess for significant differences between complication and recurrence rates with regard to the variables of interest. For statistical assessment of significance between outcomes with regard to surgical approach, *t* tests were used. Relative risks with 95 percent confidence intervals were analyzed. The significance was set to a 95 percent confidence level ($p < 0.05$). The statistical analyses were performed using IBM SPSS Version 25.0 (IBM Corp., Armonk, N.Y.).

RESULTS

The initial search yielded 1096 articles, of which 48 were identified as duplicates. The remaining 1048 studies were screened against the inclusion/exclusion criteria using the titles and abstracts. Of 90 articles selected for full-text review, 37 were included for data synthesis (Fig. 1).

A total of 24 studies (1253 patients) described 31 technical variations of an open repair approach,[9,14–37] whereas 14 articles (608 patients)

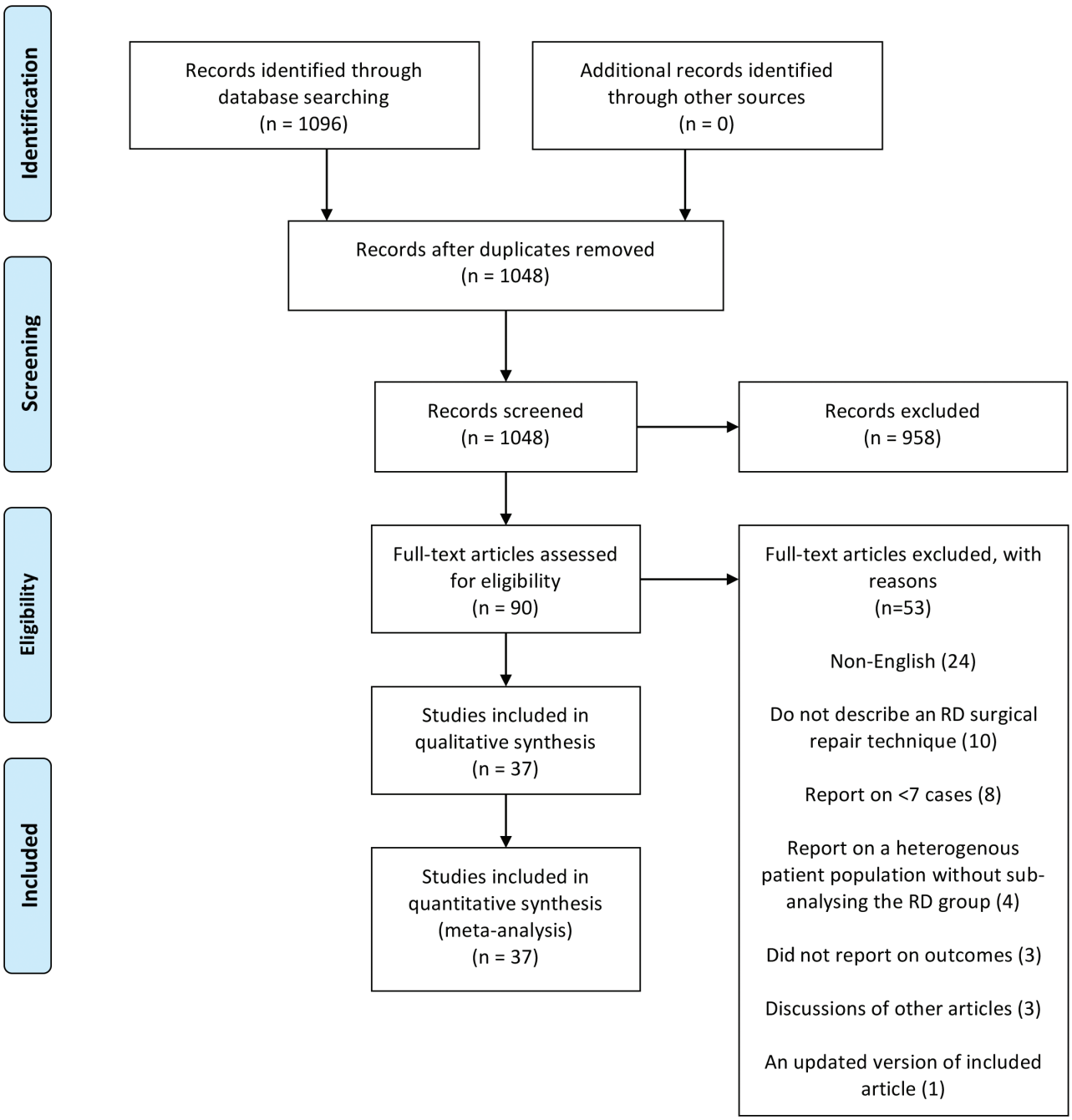

Fig. 1. Search and screening process according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

described laparoscopic repairs.[37–50] Rectus diastasis repairs were performed by both plastic (21 studies) and general surgeons (13 studies). Open repairs were performed mainly by plastic surgeons (82 percent of open repair studies), whereas laparoscopic repairs were performed mainly by general surgeons (75 percent of laparoscopic repair studies). Abdominoplasty was the primary indication for surgery in the majority of studies ($n = 20$).

The majority of rectus diastasis repair techniques, whether open or laparoscopic, consisted of either a single- or double-layer suture closure of the rectus fascia. Although minor variations existed between the individual study techniques, single-layer closure usually consisted of either running or interrupted horizontal/triangular mattress suturing. Double-layer closure consisted of an initial layer of simple-interrupted suturing followed by a second layer of running suturing, or two layers of running suturing. The most common type of suture used for rectus fascia repair was nonabsorbable. Specifically, of the 30 open techniques that mentioned the suture type, 18 (60 percent) used nonabsorbable, 11 (37 percent) used absorbable, and one (3 percent) plication technique used staples. Of the absorbable sutures, long-acting polydioxanone was more frequently used compared to short-acting Vicryl (Ethicon, Inc., Somerville, N.J.) (72.7 percent and 21.3 percent, respectively). Furthermore, of 11 laparoscopic techniques that stated their suture type, nine used nonabsorbable sutures (82 percent), one used long-acting absorbable polydioxanone (9 percent), and one used a combination of long-acting absorbable and nonabsorbable sutures (9 percent). A description of each study's rectus diastasis repair technique and reported complications are presented in Tables 1 and 2. [**See Table, Supplemental Digital Content 1**, which shows rectus diastasis (*RD*) open repair techniques along with their associated repairs of complication and recurrences, ***http://links.lww.com/PRS/E240***. **See Table, Supplemental Digital Content 2**, which shows rectus diastasis (*RD*) laparoscopic repair techniques along with their associated repairs of complication and recurrences, ***http://links.lww.com/PRS/E241***.]

On average, the surgical time for open repairs was significantly higher than for laparoscopic diastasis repairs: 162 minutes compared to 87 minutes ($p < 0.001$). However, it is important to note that this time refers to the total surgical time and not the time spent on rectus diastasis repair only. Open techniques were associated with an average length of hospital stay of 3.3 days, whereas laparoscopic techniques were found to be associated with a length of stay of 2.7 days ($p = 0.237$). With regard to patient satisfaction and postoperative pain, both outcomes were challenging to quantitatively analyze because they were often measured using different scales in different studies. However, qualitatively both laparoscopic and open techniques were generally associated with very high patient satisfaction and "well-controlled pain" (Tables 3 and 4).

The most commonly reported complications were the following: seroma, dehiscence/necrosis, bleeding/hematoma, infection, chronic pain/neuralgia, thromboembolic events, and others. A pooled analysis of total and specific complications showed that open surgery rectus diastasis repair was associated with a statistically significant lower total complication rate compared with laparoscopic surgery (12.3 percent at follow-up of 24.6 months and 16.0 percent at follow-up of 13.4 months, respectively; $p = 0.037$). The most common type of complication in both open and laparoscopic rectus diastasis repair was seroma (4.4 percent and 8.2 percent, respectively; $p = 0.002$) followed by dehiscence/skin necrosis (1.9 percent and 2.1 percent, respectively; $p = 0.856$). Notably, although thromboembolic events were very rare, they were only associated with open rectus diastasis repairs (Table 5). Laparoscopic rectus diastasis repairs were usually in the context of a herniorrhaphy: 53.2 percent of laparoscopic rectus diastasis repairs were performed alongside a hernia repair, whereas only 12.4 percent of open rectus diastasis repairs were performed with a herniorrhaphy. Because a ventral hernia repair constitutes a significant cofounding factor on surgical complication and recurrence rates, a qualitative subanalysis was performed. After controlling for this variable, open repair techniques were still associated with fewer complications in subpopulations of patients both with and without hernia repair ($p = 0.165$ and $p = 0.133$, respectively) (Table 6). Finally, there were no differences in total recurrence rates in open and laparoscopic rectus diastasis repairs (1.1 percent at follow-up of 24.6 months and 0.3 percent at follow-up of 13.4 months, respectively; $p = 0.136$). The subanalysis of rectus diastasis recurrence rates performed controlling for associated hernia repair also showed no statistically significant difference between open and laparoscopic repairs (Table 6).

Single-layer suture closure was associated with a significantly higher complication rate than double-layer plication in open rectus diastasis repairs ($p = 0.002$). In laparoscopic rectus diastasis

Table 1. Complications Profile of Open Rectus Diastasis Repair*

Open RD Repair Techniques	Reference	No. of Patients	Seroma	Dehiscence/ Necrosis	Hematomas	Infection	Chronic Pain/ Neuralgia (Can Remove)	DVT/PE	Recurrence	Other Complications (no.)
Double-layer using nonabsorbable sutures										
No mesh	Asaadi et al., 1994 Gama et al., 2017 (G3) Munhoz et al., 2005 Nahas et al., 2001 Nahas et al., 2005 Vera Cucchiaro et al., 2017	391	10	6	0	0	0	4	2	Hypertrophic scarring (3) Dog-ears (2) Scar revision (13)
Mesh	van Schalkwyk et al., 2018	10	0	0	0	0	0	0	0	None
Single-layer using nonabsorbable sutures										
No mesh	Dabb et al., 2004 Gama et al., 2017 (G1 and 2) Jansen et al., 1995 Ramirez et al., 2000 Verissimo et al., 2014	205	10	3	0	1	0	4	3	None
Mesh	Cheesborough et al., 2014 Kaddoura et al., 1998 Prado et al., 2004 Shirah et al., 2016	252	11	0	5	11	0	0	0	Hyperpigmentation (8) Dog-ear (4)
Double-layer using absorbable sutures										
No mesh	Emanuelsson et al., 2016 Nahas et al., 2001 Nahas et al., 2011 Rosen et al., 2011	83	6	0	1	0	0	0	1	None
Mesh	Matei et al., 2014	44	0	1	0	0	0	0	NS	None
Single-layer using absorbable sutures										
No mesh	Kulhanek et al., 2013 Mestak et al., 2012	101	5	8	0	0	0	0	0	Granuloma (1)
Mesh	Batchvarova et al., 2008 Emanuelsson et al., 2016 Shipkov et al., 2017	91	4	2	0	0	0	0	0	Bladder injury (1)
Single-layer using staples										
No mesh	Jansen et al., 1995	20	0	0	0	0	0	0	0	None

RD, rectus diastasis; NS, not specified; DVT, deep vein thrombosis; PE, pulmonary embolism.
*Quantitative synthesis of information pertaining to RD open repair techniques, number of patients, and complication and recurrence rates. Ferreira et al., 2001, not included, as specific suture type is not reported.

Table 2. Complications Profile of Laparoscopic Rectus Diastasis Repair*

Laparoscopic RD Repair Techniques	References	No. of Patients	Seromas	Dehiscence/ Necrosis	Hematomas	Infections	Chronic Pain/ Neuralgia	DVT/PE	Recurrences	No. of Other Complications (no.)
Double-layer using nonabsorbable sutures										
No mesh	Chang et al., 2012	88	3	1	0	0	0	0	NS	Hypertrophic scarring (3) Ecchymosis (4) Dyspnea (1)
Mesh	Li et al., 2018	26	2	0	0	0	0	0	0	None
Single-layer using nonabsorbable sutures										
No mesh	Iglesias et al., 2006 Zukowski et al., 1998	92	7	3	0	1	3	0	0	Dyspnea (2)
Mesh	Bellido Luque et al., 2015 Gomez-Menchero et al., 2018 Kockerling et al., 2017 Palanivelu et al., 2009 Shirah et al., 2016 Weissner et al., 2017	270	17	9	2	0	7	0	0	Subcutaneous emphysema (2) Pneumonia (1) Foreign body sensation (3)
Double-layer using absorbable sutures										
No mesh	—	—	—	—	—	—	—	—	—	—
Mesh	—	—	—	—	—	—	—	—	—	—
Single-layer using absorbable sutures										
No mesh	—	—	—	—	—	—	—	—	—	—
Mesh	Kohler et al., 2018	20	2	0	0	0	1	0	0	None

RD, rectus diastasis; NS, not specified; DVT, deep vein thrombosis; PE, pulmonary embolism.
*Quantitative synthesis of information pertaining to RD laparoscopic repair techniques, number of patients, and complication and recurrence rates. Carrara et al., 2019, Claus et al., 2018, and Juarez Muas, 2019, not included, as specific suture type is not reported or a mix of suture types is used.

Table 3. Study Characteristics and Outcomes of Open Rectus Diastasis Repair Techniques*

Reference	Study Type (Study Groups)	No. of Patients	Mean Age (% Female)	Primary Surgeon Department	Indication	Incision	Average Follow-Up (mo)	Type of Suture Used for RD Repair	Type of Mesh Used for RD Repair	Main Outcomes
Asaadi et al., 1994	Retrospective case review	39	NS (NS)	Plastic surgery	NS	Midline vertical	25	Nonabsorbable (0-nylon)	None	• Patient satisfaction: 100%
Batchvarova et al., 2008	Retrospective case review	52	39 (100)	Plastic surgery	Abdominoplasty for musculoaponeurotic laxity	Suprapubic horizontal	54	Absorbable (0 Vicryl)	Vicryl mesh	• Patient satisfaction: 100% • Surgical time: 3–5 hr • Hospital stay: 1–3 nights • Return to normal function: 3 wk
Cheesborough et al., 2014	Retrospective case review	32	53 (91)	NS	Ventral hernia and RD	Midline vertical	7.9	Nonabsorbable (0 polypropylene)	Midweight polypropylene uncoated mesh	• Surgical time: 151 min
Dabb et al., 2004	Retrospective case review	32	NS (NS)	Plastic surgery	Abdominoplasty for RD	Periumbilical with or without 1-inch suprapubic horizontal	12	Nonabsorbable (0 Ethibond)	None	• Return to normal function: 10 days

(*Continued*)

Table 3. ***Continued***

Reference	Study Type (Study Groups)	No. of Patients	Mean Age (% Female)	Primary Surgeon Department	Indication	Incision	Average Follow-Up (mo)	Type of Suture Used for RD Repair	Type of Mesh Used for RD Repair	Main Outcomes
Emanuelsson et al., 2016	RCT (G1: retromusclular mesh G2: double-layer suturing G3: 3-mo training program)	T: 86 G1: 29 G2: 27 G3: 30	T: (98) G1: 42 G2: 39.6 G3: 44.2	NS	Abdominoplasty for back pain	NS	12	G1: absorbable (2-0 PDS) G2: absorbable barbed (Quill PDO)	G1: lightweight polypropylene mesh	• Pain: G1 and G2 significant improvement compared to G3; no difference between G1 and G2 • Other: strength significantly improved in G1 and G2 compared to G3; no difference between G1 and G2
Ferreira et al., 2001	Retrospective case review	56	NS (NS)	Plastic surgery	Abdominoplasty for RD	Suprapubic horizontal	36	NS	None	• Other; no epigastric bulging in 100% of patients
Gama et al., 2017	RCT G1: nylon suture G2: barbed suture C: double-layer nylon suturing	T: 30 G1: 10 G2: 10 C:10	T: (100) G1: 37.9 G2: 36 C: 36.7	NS	NS	Suprapubic horizontal	NS	G1 and C: nonabsorbable (2-0 nylon) G2: nonabsorbable barbed (Quill polypropylene)	None	• Surgical time: G1, 186 min; G2, 175 min ($p < 0.05$); C, 214 min ($p < 0.005$) • Other: no difference in tensile forces of aponeuroses
Jansen et al., 1995	RCT G1: suture closure G2: staple closure	T: 38 G1: 18 G2: 20	NS (NS)	Plastic surgery	NS	NS	NS	G1: nonabsorbable (NS) G2: no suture (staples)	None	• Plication time: G1, 62 min; G2, 9 min ($p < 0.05$) • Radiologic outcome: no significant difference in separation of fascial edge at 6 mo postoperatively
Kaddoura et al., 1998	Retrospective case review	21	38 (100)	Plastic surgery	Abdominoplasty for musculoaponeurotic laxity	NS	10	Nonabsorbable (0-nylon) or staples	Polypropylene mesh	• Plication time: 38 min • Hospital stay: 3 days • Other: weight and waist circumference decreased postoperatively
Kulhanek et al., 2013	Retrospective case review	50	NS (100)	Plastic surgery	Umbilical hernia and RD	Suprapubic horizontal	60	Absorbable (0-PDS)	None	• Patient satisfaction: 98%
Mastek et al., 2012	Prospective	51	41 (100)	Plastic surgery	Cosmetic abdominoplasty	Suprapubic horizontal	20.8	Absorbable (0-PDS)	None	• Return to normal function: 51.5 days • Radiologic outcomes: U/S at 20.8 mo postoperatively showed no significant difference in IRD between study population and nulliparous control group ($p < 0.05$)
Matei et al., 2014	Retrospective case review	44	60.2 (NS)	General surgery	Umbilical hernia and RD	Midline vertical plus periumbilical dovetail	NS	Absorbable (2-0 Vicryl)	Lightweight polypropylene mesh	• Surgical time: 93 min • Hospital stay: 5.9 days • Pain: postoperative opioid treatment required for a median of 3.3 days
Munhoz et al., 2005	Retrospective case review	44	56 (100)	Plastic surgery	DIEP flap for breast reconstruction	Suprapubic horizontal	23	Nonabsorbable (2-0 nylon)	None	• Patient satisfaction: 93% • Surgical time: 407 min • Other: all patients achieved an improved abdominal contour as verified by preoperative and postoperative photographs
Nahas et al., 2001	RCT G1: nylon suture G2: PDS suture	T: 20 G1: 10 G2: 10	T: (100) G1: 32.5 G2: 38.5	Plastic surgery	Cosmetic abdominoplasty	Suprapubic horizontal	6	G1: nonabsorbable (2-0 nylon) G2: absorbable (0 PDS)	None	• Patient satisfaction: 100% • Radiologic outcomes: CT scan at 6 mo postoperatively showed maintenance of repair in all • Other: improvement in body contour in all patients

(*Continued*)

Table 3. *Continued*

Reference	Study Type (Study Groups)	No. of Patients	Mean Age (% Female)	Primary Surgeon Department	Indication	Incision	Average Follow-Up (mo)	Type of Suture Used for RD Repair	Type of Mesh Used for RD Repair	Main Outcomes
Nahas et al., 2005	Prospective	12	37 (100)	Plastic surgery	Cosmetic abdominoplasty	Suprapubic horizontal	NS	Nonabsorbable (2-0 nylon)	None	• Patient satisfaction: 100% • Radiologic outcomes: CT scan at 6 mo postoperatively showed maintenance of repair • Other: improvement in abdominal area in all patients
Nahas et al., 2011	Prospective	12	39 (100)	General surgery	Abdominoplasty for RD	Suprapubic horizontal	40.8	Absorbable (0 PDS)	None	• Patient satisfaction: 100% • Radiologic outcomes: CT scan at 6 mo postoperatively showed maintenance of repair • Other: improvement in appearance in all patients
Prado et al., 2004	Retrospective case review	20	53 (100)	Plastic surgery	Abdominoplasty for musculoaponeurotic laxity	NS	36	Nonabsorbable (NS)	Polypropylene mesh	• Patient satisfaction: 9.2/10 • Radiologic outcome: U/S at 24 mo postoperatively on 10 cases showed no RD or mesh separation
Ramirez et al., 2000	Retrospective case review	104	NS (NS)	Plastic surgery	Cosmetic abdominoplasty	NS	NS	Nonabsorbable (0-Tavdek polyester)	None	• Patient satisfaction: 100% • Pain: 26 patients were completely relieved of their preoperative pain • Other: waist size circumference decreased by an average of 10.5 cm
Rosen et al., 2011	Retrospective case review G1: barbed sutures G2: PDS sutures	T: 34 G1: 17 G2: 17	T: (100) G1: 41.9 G2: 45.2	Plastic surgery	Cosmetic abdominoplasty	NS	G1: 27 G2: 42	G1: slowly absorbable barbed (2-0 Quill PDO) G2: absorbable (0 PDS)	None	• Other: no difference between G1 and G2 in RD repair
Shipkov et al., 2017	Retrospective case review	10	35 (100)	Plastic surgery	Umbilical hernia and cosmetic abdominoplasty	Suprapubic horizontal	30	Absorbable (Vicryl)	Parietex mesh (self-fixating)	• Hospital stay: 2.4 days
Shirah et al., 2016	Retrospective case review	179	40.9 (88.2)	General surgery	Cosmetic abdominoplasty and back pain	Midline vertical	24	Nonabsorbable (0 polypropylene)	Lightweight polypropylene mesh	• Surgical time: 92.1 min • Radiologic outcomes: CT scan at 4 wk showed maintenance of repair Other: abdominal girth decreased by 12.5 cm; cosmetic outcome was excellent in 91%; abdominal muscle tone was good in 91%
van Schalkwyk et al., 2018	Prospective	10	37.2 (100)	Plastic and general surgery	Umbilical hernia and cosmetic abdominoplasty	Suprapubic horizontal plus 4 laparoscopic ports	12	Nonabsorbable barbed (1-Vloc PBT)	Parietex mesh (self-fixating)	• None
Vera Cucchiaro et al., 2017	Retrospective case review	276	28 (98.5)	Plastic surgery	Cosmetic abdominoplasty	Suprapubic horizontal	NS	Nonabsorbable (2-0 nylon)	None	• Other: progressive traction sutures only increased surgical time by 3–5 min
Verissimo et al., 2014	Prospective G1: triangular suturing G2: continuous suturing	T: 31 G1: 21 G2: 10	T: (100) G1: 33.6 G2: 376.4	Plastic surgery	Cosmetic abdominoplasty	NS	NS	G1 and G2: nonabsorbable (0-nylon)	None	• Radiologic outcome: AXRs intraoperatively and at 6 mo postoperatively were used to calculate aponeurosis shortening distance† G1: 0.93–>0.082 ($p = 0.005$) G2: 0.014–>0.005 ($p = 0.74$)

RD, rectus diastasis; NS, not specified; RCT, randomized controlled trial; T, total; G, group; C, control; PDS, polydioxanone; PDO, polydioxanone; U/S, ultrasound; IRD, interrectus distance; DIEP, deep inferior epigastric perforator; CT, computed tomography; AXRs, abdominal radiographs.

*Qualitative synthesis of information pertaining to study, diastasis size, primary surgeon department, primary reason for surgery, incision location, type of suture, and mesh used, along with their outcomes. Prospectively maintained databases were included as retrospective studies. When multiple values were present, the average was taken and reported in the table.

†Aponeurosis shortening: Ratio of mean shortening to mean distance × 100 (distance = between two clips placed 3 cm above the xiphoid process and 3 cm above the pubic symphysis).

Table 4. Included Study Characteristics and Outcomes of Laparoscopic Rectus Diastasis Repair Techniques*

Study	Study Type	No. of Patients	Mean Age (% Female)	Primary Surgeon Department	Primary Reason for Surgery	Incision	Average Follow-Up (mo)	Type of Suture Used for RD Repair	Type of Mesh Used for RD Repair	Main Outcomes
Bellido Luque et al., 2015	Prospective	21	37.6 (86)	General surgery	NS	1 cm suprapubic horizontal plus laparoscopic ports	20	Nonabsorbable (NS)	Polypropylene mesh	• Surgical time: 99 min • Patient satisfaction: 8.7/10 • Pain: significantly decreased ($p < 0.001$) • Hospital stay: 1.5 days • Radiologic outcomes: U/S at 12 mo postoperatively showed significant decrease in IRD at 3 midline locations ($p < 0.001$)
Carrara et al., 2019	Prospective	14	42 (86)	General surgery	NS	4 cm periumbilical	6	Sutures (NS) and staples	Synthetic PVDF	• Surgical time: 80 min • Pain: none postoperatively • Hospital stay: 1 day • Return to normal function: within 1 mo
Cheng et al., 2012	Retrospective case review	88	37 (100)	Plastic surgery	Abdominoplasty for RD	<5 cm suprapubic horizontal	38	Nonabsorbable (2-0 polypropylene)	None	• Surgical time: 130 min • Hospital stay: 3 days
Claus et al., 2018	Retrospective case review	48	44.3 (58.3)	General surgery	Ventral hernia and RD	2 cm suprapubic horizontal	8	Barbed (NS)	Polypropylene mesh	• Patient satisfaction: 93.7% • Surgical time: 93.5 min
Gomez-Menchero et al., 2018	Prospective	12	56.5 (41)	General surgery	Ventral hernia and RD	NS	15	Long-lasting absorbable (monofilament) or nonabsorbable barbed (1-Vloc PBT)	PVDF mesh or Dynamesh or Ventralight mesh or cPTFE mesh	• Surgical time: 54 min • Pain: significantly decreased • Hospital stay: 1.5 days • Radiologic outcomes: CT scan at 1 mo showed significant decrease in IRD ($p < 0.003$) • Other: no apparent abdominal bulging in any patient
Iglesias et al., 2006	Retrospective case review	7	35.7 (86)	Plastic surgery	Abdominoplasty for musculoaponeurotic laxity	3: suprapubic horizontal (1), right medial inguinal (1), left medial inguinal (1)	NS	Non-absorbable (2-0 Ethibond or 1-0 nylon)	None	• Patient satisfaction: 100% • Surgical time: 197 min • Hospital stay: 1.1 days • Return to normal function: 1–2 wk
Juarez Muas, 2019	Prospective	50	38 (94)	NS	Epigastric tumor/ umbilical tumor/ pain and RD	1 cm suprapubic horizontal	23	48%: absorbable barbed (0 PDS) 46%: absorbable barbed (2-0 PDS) 6%: nonabsorbable barbed (2-0 polypropylene)	Polypropylene mesh: 76% lightweight, 14% midweight; 10%: heavyweight	• Patient satisfaction: 96% • Surgical time: 83 min • Pain: 3/10 postoperatively • Hospital stay: 1.3 days • Return to normal function: 16.5 days
Kockerling et al., 2017	Retrospective	140	54.7 (NS)	General surgery	Ventral hernia and RD	2- to 3-cm periumbilical	NS	Nonabsorbable (NS)	Polypropylene mesh	• Surgical time: 116 min • Pain: 24/26 patients were completely relieved of their preoperative pain after 1 yr • Hospital stay: 4.5 days
Kohler et al., 2018	Prospective	20	41 (85)	General surgery	Ventral hernia and RD	2- to 3-cm periumbilical	5	Slowly absorbable barbed (2-0 Stratafix PDS)	Phasix mesh	• Surgical time: 79 min • Pain: 1 case of postoperative pain at 6 mo • Hospital stay: 4 days
Nahas et al., 2005	Prospective	26	48.3 (73)	General surgery	Ventral hernia and RD	3–5 laparoscopic ports	9.2	Nonabsorbable barbed (NS)	Dynamesh	• Surgical time: 107 min • Pain: 2.4/10 postoperatively • Hospital stay: 2.8 days

(*Continued*)

Table 4. *Continued

Study	Study Type	No. of Patients	Mean Age (% Female)	Primary Surgeon Department	Primary Reason for Surgery	Incision	Average Follow-Up (mo)	Type of Suture Used for RD Repair	Type of Mesh Used for RD Repair	Main Outcomes
Palanivelu et al., 2009	Retrospective case review	18	44 (NS)	NS	Cosmetic abdominoplasty	3 laparoscopic ports: 10 mm (1) 5 mm (2)	NS	Nonabsorbable (1-0 nylon)	Composite mesh	• Surgical time: 113 min • Pain: 2 cases of postoperative pain at 6 wk • Radiologic outcomes: CT scan postoperatively showed maintenance of RD repair
Shirah et al., 2016	Retrospective case review	37	40.9 (70.3)	General surgery	Cosmetic abdominoplasty and back pain	3 laparoscopic ports: 10 mm (1) 5 mm (2)	24	Nonabsorbable (0 polypropylene)	Polypropylene mesh	• Surgical time: 127.1 min • Radiologic outcomes: CT scan at 4 wk showed maintenance of RD repair • Other: abdominal girth decreased by 11 cm; cosmetic outcome was excellent in 75.7%; abdominal muscle tone was good in 91%
Weissner et al., 2017	Retrospective	42	63.5 (40)	General surgery	Ventral hernia repair and RD	3 laparoscopic ports	10	Nonabsorbable barbed (1-Vloc PBT)	Dynamesh	• Patient satisfaction: 100% • Surgical time: 92.4 min • Pain: 1 case of postoperative chronic pain • Hospital stay: 4.6 days
Zukowski et al., 1998	Retrospective	85	33 (100)	Plastic surgery	Abdominoplasty for RD	3 laparoscopic ports	NS	Non-absorbable (2-0 nylon)	None	• Surgical time: 127 min • Pain: 3 cases of postoperative chronic pain • Hospital stay: 1 day

RD, rectus diastasis; NS, not specified; PVDF, polyvinylidene difluoride; U/S, ultrasound; IRD, interrectus distance; cPTFE, condensed polytetrafluoroethylene.
*Qualitative synthesis of information pertaining to study, diastasis size, primary surgeon department, primary reason for surgery, incision location, type of suture, and mesh used, along with their outcomes. Prospectively maintained databases were included as retrospective studies. When multiple values were present, the average was taken and reported in the table.

Table 5. Pooled Analysis of Complication Rates of Open and Laparoscopic Rectus Diastasis Repair Techniques

Main Surgical Approach	Rate of Seroma	Rate of Dehiscence/ Necrosis	Rate of Bleeding/ Hematoma	Rate of Infection	Rate of Chronic Pain/Neuralgia	Rate of Thromboembolic Events (DVT/PE)	Rate of Other Complications*	Total Rate of Complications
Open ($n = 1035$)	4.4%	1.9%	0.6%	1.2%	0%	0.4%	3.8%	12.3%
Laparoscopic ($n = 608$)	8.2%	2.1%	0.3%	0.3%	1.8%	0%	3.1%	16.0%
p†	0.002	0.856	0.718	0.097	<0.001	0.303	0.580	0.037
Relative risk	0.54	0.90	1.76	3.52	0.03	5.29	1.21	0.77
95% CI	0.37–0.80	0.45–1.90	0.36–8.70	0.79–15.70	0.002–0.43	0.29–98.10	0.70–2.07	0.60–0.98

DVT, deep vein thrombosis; PE, pulmonary embolism.
*Other complications include scar revision, foreign body sensation, dog-ears, granulomas, hyperpigmentation, bladder injury, pneumonia, subcutaneous emphysema, ecchymosis, and epidermolysis (n = total number of patients included in pooled-analysis).
†Measured using either χ^2 test or Fisher's exact test based on sample size.

Table 6. Pooled Analysis of Total Rate of Complications and Recurrence of Open and Laparoscopic Rectus Diastasis Repair Techniques Stratified Based on Presence of Herniorrhaphy, Type of Layer Closure, and Suture Type*

	Rate of Complication		Rate of Recurrence	
	Open (%)	Laparoscopic (%)	Open (%)	Laparoscopic (%)
Associated hernia repair				
Yes	155 (10.97)	323 (15.79)	102 (0)	323 (0.31)
No	880 (12.50)	285 (16.10)	614 (0.98)	197 (0)
p†	0.690	0.901	0.602	1
Relative risk	0.88	0.98	0.46	1.83
95% CI	0.54–1.42	0.68–1.41	0.03–8.09	0.08–44.8
Suture closure				
Single-layer	529 (15.3)	520 (16.3)	508 (1.0)	380 (0.3)
Double-layer	506 (9.1)	114 (12.3)	208 (1.4)	26 (0)
p†	0.002	0.320	0.697	1
Relative risk	1.68	1.33	0.68	0.21
95% CI	1.20–2.37	0.79–2.26	0.16–2.83	0.009–5.10
Suture type				
Long-acting absorbable‡	150 (15.3)	20 (15)	162 (0.62)	67 (0)
Short-acting absorbable§	106 (9.4)	N/A	62 (0)	N/A
Nonabsorbable‖	758 (10.8)	464 (14.4)	492 (1.02)	379 (0)
p†	0.251	1	0.668	1
Relative risk	N/A	1.04	N/A	5.59
95% CI	N/A	0.36–3.02	N/A	0.11–279.3

N/A, not applicable.
*n = total number of patients included in pooled analysis.
†Measured using either χ^2 test or Fisher's exact test based on sample size.
‡Long-acting absorbable sutures include polydioxanone and Quill polydioxanone.
§Short-acting absorbable sutures include Vicryl.
‖Nonabsorbable sutures include nylon, polypropylene, Quill polypropylene, Ethibond, Tavdek polyester, and Vloc PBT.

repairs, a single-layer closure was associated with a higher complication rate compared to double-layer plication, but the difference was statistically insignificant (p = 0.320). Moreover, there were no significant differences in recurrence rates between single- and double-layer suture closure in both open and laparoscopic rectus diastasis repairs (p = 0.697 and p = 1.000, respectively). Finally, regardless of the rectus diastasis repair approach, the absorbability of the suture used did not have a statistically significant effect on complication or recurrence rate (Table 6).

DISCUSSION

This literature review presents an evidence-based, comprehensive summary of all surgical rectus diastasis repair techniques and quantitatively compares them. After controlling for an associated herniorrhaphy, the results demonstrate that there are no significant differences between open and laparoscopic approaches with regard to complication and recurrence rates. Furthermore, although the absorbability of the suture type used had no effect on either complications or recurrence rate, a double-layer closure of the rectus fascia was associated with fewer complications than a single-layer closure, specifically, in open rectus diastasis repairs.

Overall, both open and laparoscopic approaches for the repair of rectus diastasis were found to be safe and effective as evidenced by the low recurrence and overall complication rates. In the quickly evolving field of minimally invasive surgery, novel laparoscopic techniques are often being chosen over open surgical procedures. Although open surgery provides better visualization of the surgical field and fewer intraoperative challenges, minimally invasive surgery is commonly associated with fewer postoperative complications—most notably, postoperative pain, earlier recovery, increased patient satisfaction, and a smaller scar.[51] As the majority of patients seeking repair for their rectus diastasis are seeking functional and aesthetic improvement, a laparoscopic approach can potentially offer a better cosmetic outcome with smaller scars than the traditional open incision.[52] Novel minimally invasive techniques, such as the one described by Bellido et al., demonstrate that rectus diastasis can be repaired using a completely endoscopic technique with very minimal scarring.[13] Furthermore, a recent study has demonstrated good cosmetic outcomes after rectus diastasis repair using robotic surgery.[53] However, none of the aforementioned minimally invasive approaches involved skin resection. Given that many patients also seek excess skin removal in

addition to rectus diastasis correction, this must be taken into account when selecting the most appropriate technique to suit the patients' needs and desires.

There is a lack of consensus with regard to the optimal suture type with which to plicate the rectus abdominis sheath. The data presented in this review show that although both absorbable and nonabsorbable sutures are appropriate for rectus diastasis repair, the latter are more commonly used. The common concern is that absorbable sutures will not have enough tensile force to withstand the opposing forces of the rectus muscles. Both this review and previous literature comparing nylon (nonabsorbable) and polydioxanone (long-acting absorbable) sutures demonstrate that there is no difference in recurrence or complication rates between the suture types at long-term follow-up.[54] Moreover, recently, there has been growing interest in the use of barbed sutures in rectus diastasis repair.[55] Although several studies showed that barbed sutures were equally effective in repairing rectus diastasis and indeed associated with a shorter operative time when compared to polydioxanone or nylon sutures,[56] other studies have reported recurrence rates as high as 30 percent with the use of the knotless sutures.[57] Finally, only one study used staples for the rectus diastasis repair. According to this study, staple plication is associated with a significantly shorter operative time and is equally as effective in keeping the rectus fascial edges unseparated compared to nonabsorbable sutures, as demonstrated by radiologic imaging.[58]

In a similar effort to decrease intraoperative time while providing efficient plication of the recti, some surgeons opt for a single-layer over a double-layer closure. Although some studies show that a single-layer closure is equally effective and more efficient than a double-layer closure,[57] the pooled analysis of this review shows that a double-layer closure is associated with significantly lower complication rates. However, there were no significant differences in recurrence rates between single- and double-layer closure. Based on these results, the authors of the present article recommend a double-layer closure/plication to avoid an increased risk of complications.

This review has several limitations. The heterogeneity in surgical technique, patient population and their comorbidities, context of repair, and study type make a meta-analysis challenging to perform. Moreover, because of the absence of the information in several of the articles, the pooled analyses of the complication and recurrence rates do not control for factors such as indication for surgery, preoperative severity of rectus diastasis, associated comorbidities, and smoking status. Furthermore, because of the strict inclusion and exclusion criteria of this review, some interesting rectus diastasis repair techniques in the literature were not included, as they did not report outcomes or complications. For example, Shestak et al. describe a unique short-scar technique that is said to benefit patients requiring less extensive abdominoplasties to correct less severe abdominal deformities.[59] Another limitation of the study is the inclusion of multiple studies with varying levels of evidence. Although the authors believe that making this a true systematic review by including only prospective or randomized controlled studies could have strengthened the findings/conclusions, this was countered by the fact that unfortunately most of the articles on surgical management of rectus diastasis are retrospective in nature. As one of the primary goals of this review was to provide a comprehensive overview of all surgical management techniques of rectus diastasis, highlight their differences, and provide pooled analysis of complications and recurrence rates, a scoping review of the literature was chosen to enhance the practical application to the reader. Moreover, because some of the articles included in this review had the same author groups, it is ambiguous whether more than one of the studies report on the same patient population, which may have influenced the pooled analyses performed. Future studies should randomly assign patients to receive different surgical treatments of rectus diastasis to directly compare their outcomes and complication profiles. Furthermore, a recent study on five patients undergoing robotic rectus diastasis repair showed good cosmetic results and no complications. As robotic operations become more common in rectus diastasis repair, more studies are warranted to assess their outcomes, complications, and recurrence rates. Finally, there is a significant paucity of patient-reported outcomes in studies in this review. Because of the importance of the cosmetic outcome of rectus diastasis repair, future studies should include patient-reported outcomes to accurately assess how satisfied patients are with their overall results.

CONCLUSIONS

This literature review provides an updated overview of the current surgical treatment methods of rectus diastasis. Data from 37 included studies demonstrate that both laparoscopic and open

surgical approaches for rectus diastasis repair are safe and effective. A pooled analysis further shows that a double-layer suture closure is associated with fewer complications than a single-layer suture closure. Finally, there was no statistically significant difference in the suture absorbability on the safety and efficacy of rectus diastasis repair. With the absence of large randomized clinical trials comparing different types of surgical treatments of rectus diastasis, reviews such as this can help provide surgeons with evidence-based outcomes of different techniques, and facilitate the informed consent process.

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