Is duodeno-jejunal bypass liner superior to pylorus preserving bariatric surgery in terms of complications and efficacy?

Istvan Bence Balint 1 · Ferenc Csaszar 2 · Krisztian Somodi 3 · Laszlo Ternyik 3 · Adrienn Biro 3 · Zsolt Kaposztas 3

Received: 8 June 2020 / Accepted: 9 February 2021 / Published online: 12 March 2021 © The Author(s) 2021

Abstract

Purpose Based on recent scientific evidence, bariatric surgery is more effective in the management of morbid obesity and related comorbidities than conservative therapy. Pylorus preserving surgical procedures (PPBS) such as laparoscopic single-anastomosis duodeno-jejunal or duodeno-ileal bypass with sleeve gastrectomy are modified duodenal switch (DS) surgical techniques. The duodeno-jejunal bypass liner (DJBL) is a novel surgical method in the inventory of metabolism focused manual interventions that excludes duodeno-jejunal mucosa from digestion, mimicking DS procedures without the risk of surgical intervention. The aim of this article is to summarize and compare differences between safety-related features and weight loss outcomes of DJBL and PPBS.

Methods A literature search was conducted in the PubMed database. Records of DJBL-related adverse events (AEs), occurrence of PPBS-related complications and reintervention rates were collected. Mean weight, mean body mass index (BMI), percent of excess of weight loss (EWL%), percent of total weight loss (TWL%) and BMI value alterations were recorded for weight loss outcomes.

Results A total of 11 publications on DJBL and 6 publications on PPBS were included, involving 800 and 1462 patients, respectively. The baseline characteristics of the patients were matched. Comparison of DJBL-related AEs and PPBS-related severe complications showed an almost equal risk (risk difference (RD): −0.03 and confidence interval (CI): −0.27 to 0.21), despite higher rates among patients having received endoscopic treatment. Overall AE and complication rates classified by Clavien-Dindo showed that PPBS was superior to DJBL due to an excess risk level of 25% (RD: 0.25, CI: 0.01–0.49). Reintervention rates were more favourable in the PPBS group, without significant differences in risk (RD: −0.03, CI: −0.27 to 0.20). However, PPBS seemed more efficient regarding weight loss outcomes at 1-year follow-up according to raw data, while meta-analysis did not reveal any significant difference (odds ratio (OR): 1.08, CI: 0.74–1.59 for BMI changes).

Registration This systematic review including meta-analysis was registered under the number of CRD42020165718 in PROSPERO registry and was conducted according to the PRISMA Statement.

Sources University Library in Kaposvar, as the member of National Electronic Information Service Program Hungary shared its data-resources – including scientific articles – with the authors.

Istvan Bence Balint
balint.istvan.bence@gmail.com; balint_istvan_bence@yahoo.com

Ferenc Csaszar
fjmailnet@gmail.com

Krisztian Somodi
somodikr@gmail.com

Laszlo Ternyik
drterlaszlo@yahoo.com

Adrienn Biro
b.adrienn5@gmail.com

Zsolt Kaposztas
zsolt.kaposztas@gmail.com

1 Department of Surgery and Vascular Surgery, Zala County Saint Rafael Hospital, H-8900 Zrínyi Miklós street 1., Zalaegerszeg, Hungary

2 Doctoral School of Neurosciences, University of Pecs, Pécs, Hungary

3 Department of Surgery, Somogy County Kaposi Mor Teaching Hospital, Kaposvár, Hungary
Conclusion Only limited conclusions can be made based on our findings. PPBS was superior to DJBL with regard to safety outcomes (GRADE IIB), which failed to support the authors’ hypothesis. Surgical procedures showed lower complication rates than the incidence of DJBL-related AEs, although it should be emphasized that the low number of PPBS-related mild to moderate complications reported could be the result of incomplete data recording from the analysed publications. Weight loss outcomes favoured bariatric surgery (GRADE IIB). As the DJBL is implanted into the upper gastrointestinal tract for 6 to 12 months, it seems a promising additional method in the inventory of metabolic interventions.

Keywords Pylorus preserving · Bariatric surgery · Metabolic surgery · Single-anastomosis duodeno-jejunal bypass · Single-anastomosis duodeno-ileal bypass · Duodenal switch · Duodeno-jejunal bypass liner · EndoBarrier

Introduction

Rationale Obesity represents a high risk for metabolic syndrome-related morbidities, such as hypertension, dyslipidaemia, prediabetes (hyperinsulinemia, impaired fasting glucose) and type II diabetes mellitus, resulting in various forms of cardiovascular disease [1, 2]. According to recent scientific evidence, bariatric surgery is the most efficient method to obtain weight loss. However, there is significant difference regarding complications and weight loss outcomes, depending on the type of surgical method [3–6].

Pylorus preserving surgical procedures (PPBS) date back to the early 1990s and have advantages over gastric bypass procedures (laparoscopic Roux-en-Y gastric bypass and one-anastomosis gastric bypass, LRYGB and OAGB, respectively) due to the preservation of the pylorus by a tube-like stomach (gastric sleeve), resulting in controlled gastric emptying and prevention of afferent limb bile reflux. The single-anastomosis duodeno-jejunal and duodeno-ileal bypass with sleeve gastrectomy (SADI-SG and SADJ-SG, respectively) are the most frequently applied methods of PPBS. These procedures are variants of the duodenal switch (DS) technique, representing favourable efficacy with acceptable complication rates, and vary in applicable technique. When using SADI-SG, a part of the ileum (200–300 cm measured backwards from the ileocecal valve) is connected to the duodenal stump after performing laparoscopic sleeve gastrectomy (LSG). Identical to OAGB, the jejunum (150–200 cm measured downwards from the ligament of Treitz) is used to create the duodeno-jejunal anastomosis in SADJ-SG. Both methods have a similar effect on weight loss and metabolic improvements, with affordable complication rates [7–12].

The duodeno-jejunal bypass liner (DJBL) (EndoBarrier®, GI Dynamics, Boston, MA, USA), introduced in the late 2000s, is a novel investigational method among metabolic interventions. After initial FDA approval, it was still not widely used for years because of severe complications, such as liver abscess and pancreatitis. A 60-cm-long impermeable fluoropolymer tube is inserted endoscopically under general anaesthesia into the duodenum and becomes anchored to the pylorus (the implant secures itself) in outpatient settings. It excludes the duodeno-jejunal mucosa from digestion mimicking DS procedures without the potential risk of surgery. Favourable weight loss outcomes and metabolic control are expected by creating a physical barrier between the mucosa of the upper small intestine and the ingested food. Longitudinal temporal data on efficacy is lacking, and published complication rates are controversial [13–23].

Objective The aim of this review article is to summarize and compare differences between the procedure-related complication rates and weight loss outcomes of DJBL and PPBS by performing a meta-analysis.

Methods

Study design

This systematic review including meta-analysis was registered under #CRD42020165718 in the PROSPERO registry and was conducted according to the PRISMA Statement. The study protocol is available at the website of National Institute for Health Research (https://www.crd.york.ac.uk/PROSPERO/).

Eligibility criteria Studies (randomized controlled trials (RCTs), matched cohorts, case series) investigating DJBL and/or PPBS (SADJ-SG and/or SADI-SG) presenting adult patients (18–65-year age interval) with a body mass index (BMI) over 40, or over 35 if a metabolic indication was present, and at least 12-month follow-up after surgery and a 12-month planned and completed implantation period for DJBL were eligible. Papers presenting revisional procedures (presence of bariatric surgery in previous history) and those with sample sizes below 15 cases were excluded.

Information sources and literature search PubMed was used, with keywords ‘endobarrier’, ‘duodenojejunal bypass liner’, ‘duodeno-jejunal bypass liner’, ‘duodeno jejunal bypass liner’, ‘gastrointestinal bypass liner’, ‘gastro intestinal bypass liner’, ‘gastro-intestinal bypass liner’, ‘single anastomosis duodeno ileal bypass’, ‘single anastomosis duodenoileal bypass’, ‘single-
anastomosis duodenoileal bypass’, ‘single-anastomosis duodeno-ileal bypass’, ‘one anastomosis duodeno ileal bypass’, ‘one anastomosis duodenoileal bypass’, ‘one anastomosis duodeno-ileal bypass’, ‘one-anastomosis duodenoileal bypass’, ‘one-anastomosis duodeno ileal bypass’, ‘single anastomosis duodeno jejunal bypass’, ‘single anastomosis duodenojejunal bypass’, ‘single anastomosis duodenojejunal bypass’, ‘single-anastomosis duodenojejunal bypass’, ‘one anastomosis duodeno jejunal bypass’, ‘one anastomosis duodenojejunal bypass’, ‘one-anastomosis duodenojejunal bypass’ and ‘one-anastomosis duodeno-jejunal bypass’, without language restrictions and filters, to include studies on investigated methods until a publication date of 30th of March, 2020.

**Study selection** After identifying publications through the database search, duplicates were removed. Through screening, some studies not meeting the eligibility criteria were excluded.

The remaining articles were retrieved for complex evaluation. After removing full-text papers not meeting the eligibility criteria, studies were included into qualitative and quantitative analysis. Studies with overlapping records were excluded from the final evaluation.

**Data collection** Outcomes of safety and weight loss were collected from individual studies after duplications were excluded.

**Data items** The number of adverse events (AEs) of DJBL and complications (CD 1–5) of surgeries were collected for safety analysis. Mean weight, mean BMI, percent of excess of weight loss (EWL%), percent of total weight loss (TWL%) and changes of BMI at 1-year follow-up after initial intervention were recorded for weight loss outcomes. Categorical variables were presented as number and percentage. Continuous variables were presented by mean, range and SD, where possible.

---

**Fig. 1** Flow diagram of studies

- Records identified through database searching (n = 505)
- Additional records identified through other sources (n = 0)
- Records excluded (n = 162)
  - complication n=13
  - review n=44
  - animal study n=24
  - revisional surgery n=14
  - case report n=5
  - technical note n=6
  - no abstract n=3
  - no matching data n=5
  - consensus document n=2
  - study protocol n=1
  - editorial n=6
  - other n=39
- Full-text articles excluded, with reasons (n = 43)
  - sample size does not reach inclusion criteria n=4
  - low BMI of included cases n=15
  - follow up does not reach 12 months n=12
  - reporting different procedure n= 8
  - ongoing trial n=2
  - other n=2
| Authorship | Year of publication | Country | Study design | Method | Number of cases treated by the investigated method | Follow-up (Implantation period + postimplantation period for DJBL) | Classification of complications by Clavien-Dindo (determined by authors) |
|------------|---------------------|---------|--------------|--------|-----------------------------------------------|-------------------------------------------------|-------------------------------------------------|
|            |                     |         |              |        |                                               | CD1    | CD2    | CD3a   | CD3b   | CD4a   | CD4b   | CD5    |
| Roehlen et al. | 2020 | Germany | Single-centre prospective cohort | DJBL  | 71 | 12 months | 66 | 18 | 155 | 0 | 2 | 0 | 0 |
| Homan et al. | 2019 | Slovenia | Single-centre prospective cohort | DJBL  | 19 | 12+12 months | 14 | 0 | 33 | 1 | 1 | 0 | 0 |
| Deutsch et al. | 2018 | Israel | Single-centre prospective cohort | DJBL  | 51 | 12+12 months | 6 | 2 | 59 | 0 | 0 | 0 | 0 |
| Laubner et al. | 2018 | Germany | Multicentre prospective matched cohort (DJBL and DPV registry) | DJBL vs. Conservative treatment (2:1) | 235 | 12 months | 81 | 11 | 327 | 0 | 0 | 0 | 0 |
| Patel et al. | 2018 | United Kingdom | Multicentre prospective cohort (DJBL and DPV registry) | DJBL  | 45 | 12+6 months | 98 | 33 | 176 | 1 | 0 | 0 | 0 |
| Riedel et al. | 2018 | Germany | Multicentre prospective cohort (DJBL registry) | DJBL  | 66 | 12 months | 28 | 5 | 99 | 0 | 0 | 0 | 0 |
| Forner et al. | 2017 | Australia | Two-centre retrospective cohort | DJBL  | 114 | 12+6 months | 84 | 32 | 230 | 0 | 1 | 0 | 0 |
| Quezada et al. | 2017 | Chile | Single-centre prospective cohort | DJBL  | 80 | 12+24 months | 37 | 8 | 125 | 0 | 2 | 0 | 0 |
| Stratmann et al. | 2016 | Germany | Single-centre prospective cohort | DJBL  | 18 | 12 months | 0 | 1 | 19 | 0 | 0 | 0 | 0 |
| Munoz et al. | 2013 | Chile | Single-centre prospective cohort | DJBL  | 79 | 12 months | 0 | 4 | 83 | 0 | 0 | 0 | 0 |
| de Moura et al. | 2012 | Brazil | Single-centre prospective cohort | DJBL  | 22 | 12 months | 33 | 5 | 60 | 0 | 0 | 0 | 0 |
| Surve et al. | 2020 | Australia | Single-centre prospective cohort | SADI-SG | 91 | 2 years | 0 | 4 | 0 | 0 | 0 | 0 | 0 |
| Surve et al. | 2018 | Multinational | International retrospective mixed cohort | SADI-SG | 598 | 12 months | 0 | 0 | 5 | 7 | 0 | 0 | 0 |
| Zaveri et al. | 2018 | USA | Two-centre prospective cohort | SADI-SG | 437 | 4 years | 20 | 22 | 2 | 35 | 0 | 0 | 0 |
| Moon et al. | 2017 | USA | Single-centre prospective cohort | SADI-SG | 140 | 2 years | 0 | 28 | 0 | 17 | 0 | 0 | 0 | 0 |

1 leak, 1 cardiac arrest, 1 sudden cardiac death probably due to OSA
Bias A wide search without language restriction and filters was undertaken in an attempt to minimize selection bias. All available study types were included to increase the sample size, causing bias due to insecure parameters with weak statistical results. Heterogeneity tests (Cochran’s Q, \( I^2 \) consistency and chi-square tests) were performed to verify validity (the \( p \) value was set at 0.05). Doi plots were presented to detect publication bias. The IVhet method was applied for meta-analysis to minimize underestimation of statistical error [24–28].

Summary measures AEs and complications were compared by risk difference (RD) between the investigated methods. Odds ratios (ORs) are presented for weight loss outcomes (BMI comparison).

Synthesis of results MetaXL software (ver. 5.3, additional software for Microsoft Excel, EpiGear International) was applied. The IVhet model was chosen for meta-analysis, which is an inverse variance method developed by Doi et al., to keep the coverage at the usual 95% level of confidence interval (CI) and maintain the inverse variance weights of the studies. In case of heterogeneity, the model boosts the CI around the pooled estimate, but the study weights remain individual depending on the size of the study population [24–28].

Results

Study selection PubMed database analysis identified 505 unique publications, and 228 articles remained after duplications were removed. Overall, 23 studies met the eligibility criteria from the screened and assessed full-text publications. Due to overlap, 6 publications were excluded, leaving 17 publications in the final analysis (11 for DJBL and 6 for PPBS) [7–23]. Details are listed in the flow chart presented in Fig. 1.

Study characteristics In total, 7 single-centre prospective cohorts, 1 two-centre cohort and 3 multicentre cohorts were included for DJBL, resulting in 800 involved patients (Table 1), and 3 single-centre prospective cohorts, 1 two-centre cohort, 1 international retrospective mixed cohort and 1 small RCT were identified for PPBS, involving 1462 surgically treated cases (Table 1).

Risk of bias within studies One retrospective study was involved for safety analysis because it presented controlled results of different intervention sites. Some patients of this international retrospective mixed cohort were excluded because their cases were described in more detail in other single-centre prospective cohorts involved in the analysis, and the other publications represented high quality-controlled data on safety and efficacy. All AEs were taken into consideration without subgroups. Complications of surgeries were essentially
| Device-related AE rate | Death | Early removal | Migration | Hepatic abscess | Pancreatitis | Hepatobiliary | Anaemia | Bleeding | GIT events |
|------------------------|-------|---------------|-----------|-----------------|--------------|--------------|---------|----------|------------|
| 78                     | 0     | 20            | 4         | 3               | 2            | 1 cholangitis | 0       | 0        | 66         |
| 16                     | 0     | 0             | 0         | 0               | 1            | 1 cholangitis with cholecystectomy | 0       | 0        | 14         |
| 20                     | 0     | 10            | 0         | 2               | 0            | 0            | 0       | 2        | 6          |
| 107                    | 0     | 35            | 6         | 4               | 0            | 1 cholecystitis | 0       | 1        | 81         |
| 54                     | 0     | 6             | 2         | 0               | 0            | 1 cholecystectomy | 5       | 1        | 98         |
| 43                     | 0     | 0             | 1         | 1               | 0            | 0            | 0       | 4        | 28         |
| 84                     | 0     | 28            | 11        | 2               | 1            | 0            | 11      | 5        | 84         |
| 131                    | 0     | 23            | 9         | 3               | 2            | 0            | 0       | 5        | 37         |
| 5                      | 0     | 3             | 3         | 0               | 0            | 0            | 0       | 1        | 0          |
| 20                     | 0     | 18            | 8         | 1               | 0            | 1 cholangitis 1 cholecystitis | 0       | 1        | 0          |
| 30                     | 0     | 9             | 3         | 0               | 0            | 0            | 0       | 1        | 33         |

| Device-related AE rate | Malabsorption | Diarrhoea | Constipation | Oesophageal perforation/rupture | Duodenal perforation | Mucosal erosion | Obstruction | Other technical difficulties | Other |
|------------------------|---------------|-----------|--------------|--------------------------------|----------------------|-----------------|-------------|------------------------------|-------|
| 78                     | 0             | 11        | 6            | 0                              | 1                    | 0               | 1           | 0                            | 0     |
| 16                     | 0             | 0         | 0            | 0                              | 0                    | 0               | 0           | 0                            | 0     |
| 20                     | 0             | 0         | 0            | 0                              | 0                    | 0               | 0           | 0                            | 0     |
| 107                    | 0             | 6         | 3            | 0                              | 1                    | 1               | 2           | 0                            | 0     |
| 54                     | 18            | 4         | 4            | 0                              | 0                    | 1               | 0           | 0                            | 1     |
| 43                     | 0             | 0         | 1            | 0                              | 0                    | 7               | 1           | 0                            | 0     |
| 84                     | 11            | 3         | 0            | 0                              | 0                    | 6               | 6           | 1                            | 1     |
| 131                    | 0             | 3         | 0            | 2                              | 0                    | 1               | 2           | 0                            | 0     |
| 5                      | 0             | 0         | 0            | 0                              | 0                    | 0               | 1           | 0                            | 0     |
| 20                     | 0             | 0         | 0            | 0                              | 0                    | 0               | 5           | 0                            | 1     |
| 30                     | 0             | 1         | 0            | 0                              | 0                    | 0               | 0           | 0                            | 3     |
### Table 3  PPBS-related complications

| Overall number of complications | Death | Reoperation | VTE | Leakage | Stricture | Common channel shortening | Common channel lengthening | Afferent limb reflux | Intraabdominal abscess |
|---------------------------------|-------|-------------|-----|---------|-----------|---------------------------|---------------------------|---------------------|-----------------------|
| 4                               | 0     | 0           | 0   | 0       | 0         | 0                         | 0                         | 0                   | 0                     |
| 12                              | 0     | 0           | 0   | 6       | 5         | 0                         | 0                         | 1                   | 0                     |
| 79                              | 1 leak, 1 cardiac arrest, 1 sudden cardiac death probably due to OSA | 6 | 1 portal vein | 1 early | 13 | 0 | 8 | 4 | 2 |
| 45                              | 1 (ventricular fibrillation) | 27 | 1 DVT | 5 duodeno-ileoanastomosis/3 sleeve/2 duodenal stump | 0 | 0 | 0 | 2 | 1 |
| 41                              | 0     | 3           | 0   | 1       | 0         | 0                         | 0                         | 0                   | 0                     |
| 1                               | 0     | 1           | 0   | 0       | 0         | 0                         | 0                         | 0                   | 0                     |

| Overall number of complications | Bleeding | Wound infection | Constipation | Ileus | GIT events | Malabsorption | Diarrhoea | Small bowel perforation | Other technical difficulties | Other |
|---------------------------------|----------|-----------------|--------------|-------|-------------|---------------|-----------|-------------------------|-----------------------------|-------|
| 4                               | 2        | 0               | 0            | 0     | 0           | 0             | 0         | 0                       | 0                           | 1 euglycaemic diabetic ketoacidosis 1 respiratory insufficiency |
| 12                              | 0        | 0               | 0            | 0     | 0           | 0             | 0         | 0                       | 0                           | 0     |
| 79                              | 6        | 11              | 1            | 0     | 23          | 2             | 9         | 0                       | 3                           | 0     |
| 45                              | 0        | 0               | 0            | 0     | 2 internal hernia and twisting | 0             | 28        | 0                       | 1                           | 2 diagnostic laparoscopy | 1 gastroenteritis |
| 41                              | 1        | 0               | 0            | 0     | 0           | 38            | 0         | 0                       | 0                           | 1 umb. hernia |
| 1                               | 0        | 0               | 0            | 1     | 0           | 0             | 0         | 0                       | 0                           | 0     |
graded according to the Clavien-Dindo classification system [29, 30]. For better comparison, authors reconsidered AEs of DJBL using the Clavien-Dindo classification (CD 1, gastrointestinal (GIT) events; 2, cholangitis, anaemia, bleeding, malabsorption, diarrhoea, constipation and other difficulties; 3a, early removal, migration, hepatic abscess, perforations, erosion and obstruction; 3b, cholecystectomy; 4a, pancreatitis; 4b, no cases; 5, no cases). Three safety-related comparisons were performed (1, author defined severe events and complications; 2, overall number of AEs and CD complications; 3, reintervention rates). DJBL-related severe events included death, hepatobiliary complication, device migration, pancreatitis, mucosal injury, obstruction and bleeding. PPBS-related severe complications included venous thromboembolism (VTE), wound healing disorder, ileus, hepatobiliary complication, leakage, death, stenosis or stricture, conversion, intraabdominal abscess, bleeding, peritonitis, biliary reflux, weight regain, perforation, diagnostic laparoscopy and obstruction. Weight loss outcomes were presented by descriptive comparison of initial weight, BMI changes, EWL% and TWL% at 1 year after intervention. The meta-analysis was performed on BMI changes (mean differences with SD were estimated from individual studies and were compared to each other).

Results of individual studies In the 11 DJBL-related studies with 800 patients, the mortality rate was zero, a high rate of AEs (73.5%) was reported, and 19% of the implanted devices were explanted earlier than planned. The number of severe AEs was 155 (19.4%). In the 6 studies in the PPBS group, which included 1462 patients, 4 patients died: 1 death was a result of leakage and the other 3 deaths were not surgery related. Complications occurred at an acceptable rate (12.4% in all surgical cases), and 37 reoperations (2.5% of patients) were performed due to various reasons. In total, 5.7% (84) of all complications were listed in the severe category. AEs of DJBL and surgery-related complications are presented in Table 2 and Table 3, respectively.

Mean weight and BMI at baseline were comparable between groups, while EWL%, TWL% and BMI at 1 year were in favour of the PPBS group (76.5% vs. 33.5% for EWL%, 36.9% vs. 13.7% for TWL% and a BMI decrease of 18 vs. 4.2, respectively). Records are presented in Table 4, and a summary of complications and weight loss outcomes is detailed in Table 5.

Synthesis of results Comparison of DJBL-related severe events and PPBS-related severe complications defined by authors (Fig. 2) showed almost equal risk (RD: −0.03, CI: −0.27

### Table 4  Weight loss outcomes

| Weight loss outcomes of DJBL | Mean weight in kg at baseline | EWL% at 1 year | TWL% at 1 year | BMI in kg/m2 at baseline | BMI in kg/m2 at 1 year |
|-----------------------------|-------------------------------|----------------|----------------|--------------------------|------------------------|
| n.a.                        | n.a.                          | n.a.           | n.a.           | 45.2 ± 8.0               | 39.1 ± 7.6 (n=62)      |
| 125.3                      |                               | 11.40%         |                | 42.11                    | n.a.                   |
| 109.80 ± 17.9              |                               | 15.05 ± 6.0%   |                | 37.27 ± 4.9              | 37.47 ± 5 (n=39)       |
| 124.7 ± 22.6               |                               | 11.80%         |                | 42.8 ± 7.0               | 37.88 ± 6.7            |
| 115.6 ± 21.1               |                               | 12.99%         |                | 40.0 ±5.8                | n.a.                   |
| 125.0 ± 21.7               |                               | 15.90%         |                | 43.4 ± 6.5               | 37.9 ± 6.8 (n=65)      |
| 115 ± 21                   |                               | 11.7 ± 7.1%    |                | 39 ± 6                   | 34.8 ± 3.2             |
| 109.93 ± 17                |                               | 17.20%         |                | 42.19 ± 5                | 43.6 ± 16 (n=72)       |
| n.a.                       |                               | n.a.           |                | 48.8 ± 8.8 kg            | n.a.                   |
| n.a.                       | 46 ± 18%                      | n.a.           |                | 43 ± 5.6                 | n.a.                   |
| 119.2 ± 22.9               |                               | 39.0 ± 3.9%    |                | 44.8 ± 7.4               | 38.1 ± 0.7 (n=13)      |
| 118.1 (109.8–125, n=632)   | 33.5% (10.2–46%, n=500)       | 13.72% (11.4–17.2%, n=610) | 42.6 (37.3–48.8) | 38.4 (34.8–43.6, n=600)|

| Weight loss outcomes of PPBS | Mean weight in kg at baseline | EWL% at 1 year | TWL% at 1 year | BMI in kg/m2 at baseline | BMI in kg/m2 at 1 year |
|------------------------------|-------------------------------|----------------|----------------|--------------------------|------------------------|
| 123.4 ± 20                   | 69.2 ± 16.4% (n=62 )         | 34.6 ± 9.2% (n=62) | 43.2 ± 5.7 | 27.9 ± 3.2               |
| 142.64                      | n.a.                          | n.a.           |                | 49.94                    | n.a.                   |
| 142.65 ± 30.83              | 77.69 ± 20.92% (n=266 )      | n.a.           |                | 49.8 ± 8.8               | 31.8 ± 5.48            |
| n.a.                        | 62.4% (n=58)                  | 37.1 ± 6.6% (n=58) | 57.3 ± 9.2 | 35.3 ± 5.8               |
| 119.5                       | 91%                           | 39%            |                | 44.3                     | n.a.                   |
| n.a.                        | 81.94 ± 9.51%                | n.a.           |                | 48.28± 3.80              | 28.19 ± 2.14           |
| 132 (119.5–142.65, n=1294)  | 76.45 (62.4–91%, n=582)       | 36.9% (34.6–39%, n=288) | 48.8 (43.2–57.3) | 30.8(27.9–35.3, n=696)|

Number of patients is presented separately where it differed from the overall number. Range and SD were added where they were available and where necessary.
to 0.21). Regarding overall AE and CD complications (Fig. 3), PPBS was superior to DJBL due to an excess risk of 25% (RD: 0.25, CI: 0.01–0.49). Reintervention rates (Fig. 4) were similar (RD: −0.03, CI: −0.27 to 0.20). For weight loss outcomes, changes of BMI (Fig. 5) were compared and indicated similar efficacy for both investigated methods (OR: 1.08, CI: 0.74–1.59).

**Risk of bias across studies** In comparisons of DJBL-related severe events and PPBS-related severe complications, studies were homogenous ($Q = 8.94$, $p = 0.92$, $I^2 = 0\%$), and Doi plot (Fig. 2) warranted only a minor risk for publication bias (LFK index: 1.84). Regarding AEs and CD complications, there was no heterogeneity proven ($Q = 4.18$, $p = 1.00$, $I^2 = 0\%$), and the Doi plot (Fig. 3) showed no asymmetry (LFK index: −0.93). Studies were also homogenous when comparing reintervention rates ($Q = 9.45$, $p = 0.89$, $I^2 = 0\%$), with a minor risk of publication bias (LFK index: 1.70) (Fig. 4). There was no heterogeneity observed in the meta-analysis of BMI changes (Fig. 5), and the risk of publication bias was minor for weight loss outcomes (LFK index: −1.26).

**Discussion**

**In general** The aim of restrictive procedures is to decrease stomach volume. If the fundus is removed, satiety will emerge faster and will last longer because of lowered ghrelin levels [31]. Duodeno-jejunal exclusion results in more complex effects of gut hormones. Changes in cholecystokinin (CCK) and protein Y mechanism affect satiety. Incretins (mainly glucagon like peptide 1 (GLP1)) influence serum glucose levels by antagonizing glucagon [32–34], and the latter effects make duodeno-jejunal exclusion more efficient in weight loss management and metabolic improvement compared to solely restrictive procedures. The mechanism is independent of the type of procedure applied (gastric bypass methods or PPBS).

**Summary of evidence** Safety is the most important thing when introducing a novel method. DJBL has been regarded as being safer than bariatric surgery [35, 36]. Our opinion is that it is essential to preserve the function of the pylorus; therefore, we decided to compare this method to PPBS as a control group, because DJBL is theoretically regarded as mimicking duodeno-jejunal exclusion. SADI-SG is more frequently represented in the literature than SADJ-SG. The length of the afferent limb should affect complications and efficacy, but such a statement has not yet been proven well. Surprisingly, our meta-analysis found a higher risk of DJBL-related AEs compared to PPBS-related CD complications. Authors found fewer than expected mild to moderately severe (CD 1-2) complications (such as GIT events, malabsorption, diarrhoea) reported for PPBS. The reason could be due to inaccurate
publishing of such complications by some of the studies in the surgery group. It should be taken into consideration that cumulative mortality was zero after DJBL implantation, while four patients died in the surgical group (only one case was directly related to the intervention). Reintervention rates were unexpectedly similar between the two methods. After DJBL, early device removal was the most frequent type of reintervention. After any kind of bariatric surgery intervention, there could be various reoperations due to different indications, and there was no difference between the groups in this aspect. Each method was efficient regarding weight loss outcomes, without significant differences, yet more favourable weight management could be achieved by applying PPBS. The DJBL is usually in place for 6 months (which could be extended to 12 months), resulting in an increase in body weight after explantation, while metabolic parameters worsen. As for future prospects, we hope that the implantation period could be extended to achieve an even better outcome. After publishing long-term data on temporary metabolic procedures, we will be able to compare them with purely surgical methods in order to obtain more precise guidelines. We must emphasize the disadvantage caused by the increasing difficulty of reverting any kind of bariatric surgery (especially when part of the upper GIT is bypassed) to normal anatomy, compared to endoscopic interventions.
Comparison with other procedures
LYRGB dominated bariatric surgery for a long period of time. Later, it was replaced by LSG due to its greater simplicity and more favourable efficacy. Perioperative mortality rates are incredibly low (below 0.2%), and the rates of overall serious complications are lower than 6% for LSG and 9% for LYRGB, respectively. Short-term reoperation rates should be kept below 3% for LSG and 5% for LYRGB. The long-term TWL% of each method is around 20% [37]. The latest systematic reviews including meta-analysis showed controversial results in terms of efficacy and safety when comparing LYRGB with LSG [38–40]. OAGB was proven to be effective and safe compared to LYRGB [41, 42]. Our results are comparable to former studies on widespread bariatric surgery procedures. PPBS-related mortality (0.3%), reoperations (2.5%) and severe complications (5.7%) are comparable to widely used metabolic interventions. In contrast, there was zero mortality in the DJBL group, yet 19% of implanted devices were removed earlier, and more severe AEs (19.4%) were observed. PPBS represents similar weight loss outcomes to LYRGB, SAGB or LSG; however, DJBL provides less favourable results.

Limitations
Our review has limitations, as the included studies lack RCTs. There is a minor to moderate risk of publication bias. DJBL is a temporary method, contrary to PPBS, which has long-term efficacy; therefore, comparison could be
ambiguous. While DJBL is regarded as mimicking DS procedures, it seems to be more practical to compare it to the gold standard pylorus preserving duodeno-jejunal bypass, despite emerging concerns. Due to the lack of long-term data on the efficacy of DJBL, short-term (1-year implantation period) results were compared to the surgical group to achieve more relevant results. SADI-SG seems to provide a more hypoabsorptive effect than SADJ-SG, but there are no strong recommendations supporting this. Definitions of severe AEs varied between DJBL trials, which could confuse our results. Thus, we decided to determine which AEs were classified as severe to achieve a more accurate comparison. Mild to moderate surgical complications, especially the most frequent late side effects (malabsorption and diarrhoea), were underrepresented in the papers involved, which could skew our results. In addition, the published parameters of weight loss were not unified, which reduced the value of the comparison.

**Conclusion** Only limited conclusions can be made based on our findings. PPBS was superior to DJBL with regard to safety outcomes (GRADE IIB), which failed to support the authors’ hypothesis. Surgical procedures showed lower
complication rates than the incidence of DJBL-related AEs, although it should be emphasized that the low number of PPBS-related mild to moderate complications reported could be the result of incomplete data recording in the analysed publications. Weight loss outcomes were in favour of bariatric surgery (GRADE IIB). As the DJBL is implanted into the upper GIT for 6 to 12 months, it seems a promising additional method in the inventory of metabolic interventions.

Acknowledgements The authors thank Anna Gyodi for her help in retrieving articles from database of Kaposvar University Library.

Availability of data and material Extracted information is presented in main text or tables.

Code availability Not applicable.

Authors’ contributions BIB: study planning, writing study protocol, data extraction and interpretation, performing meta-analysis and writing. FCs: data interpretation and writing. KS: data extraction. LT: data extraction. AB: data extraction. ZsK: data interpretation and writing.

Funding Open access funding provided by Hospital Library of County Zala Saint Rafael.

Declarations

Ethics approval Ethical approval was not necessary for this study.

Consent to participate No signed informed consent was needed for this study.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

Abbreviations AE, Adverse event; BMI, Body mass index; CCK, Cholecystokinin; CD, Clavien-Dindo classification; CI, Confidence interval; DJBL, Duodeno-jejunal bypass liner; DS, Duodenal switch; EWL%, Percent of excess of weight loss; FDA, Food and Drug Administration; GIT, Gastrointestinal tract; HgbA1C%, Haemoglobin A1C in percent; LSG, Laparoscopic sleeve gastrectomy; LRYGB, Laparoscopic Roux-en-Y gastric bypass; OAGB, One-anastomosis gastric bypass; PPBS, Pylorus preserving bariatric surgery; RCT,
Randomized controlled trial; SADI-SG, Single-anastomosis duodeno-jejunal bypass with sleeve gastrectomy; SADJ-SG, Single-anastomosis duodeno-jejunal bypass with sleeve gastrectomy; SD, Standard deviation; T2DM, Type 2 diabetes mellitus; TWL%, Percent of total weight loss; RD, Risk difference; OR, Odds ratio; VTE, Venous thromboembolism

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

References

1. Neeland IJ, Poirier P, Després JP (2018) Cardiovascular and metabolic heterogeneity of obesity: clinical challenges and implications for management. Circulation 137(13):1391–1406. https://doi.org/10.1161/CIRCULATIONAHA.117.029617
2. Aschner P (2017) Recent advances in understanding/managing type 2 diabetes mellitus. F1000Res 6:pii:F1000 Faculty Rev-1922. https://doi.org/10.12688/f1000research.11192.1
3. Colquitt JL, Pickett K, Loveman E, Frampton GK (2014) Surgery for weight loss in adults. Cochrane Database Syst Rev (8):Art. No.: CD003641. https://doi.org/10.1002/14651858.CD003641.pub4
4. Lee WJ, Almulafli A (2015) Recent advances in bariatric/metabolic surgery: appraisal of clinical evidence. J Biomed Res 29(2):98–104. https://doi.org/10.7861/clinmedicine.19-3-205
5. Kang JH, Le QA (2017) Effectiveness of bariatric surgical procedures: a systematic review and network meta-analysis of randomized controlled trials. Medicine (Baltimore) 96(46):e8632. https://doi.org/10.1097/MD.0000000000008632
6. Ruban A, Stoenchev K, Ashrafian H, Teare J (2019) Current treatments for obesity. Clin Med (Lond) 19(3):205–212. https://doi.org/10.7861/clinmedicine.19-3-205
7. Surve A, Rao R, Cottam D, Rao A, Ide L, Cottam S, Horsley B (2020) Early outcomes of primary SADI-S: an Australian experience. Obes Surg 30(4):1429–1436. https://doi.org/10.1007/s11695-019-04312-6
8. Surve A, Cottam D, Sanchez-Pernaute A, Torres A, Roller J, Kwon Y, Mourtou J, Schniederman B, Neichoy B, Enochs P, Tyner M, Bruce J, Bovard S, Roslin M, Jawad M, Teixeira A, Srikanth M, Free J, Zaveri H, Pilati D, Bull J, Belnap L, Richards C, Medlin W, Moon R, Cottam A, Sabruidin S, Cottam S, Dhorepatil A (2018) The incidence of complications associated with loop duodeno-ileostomy after single-anastomosis duodenal switch procedures among 1328 patients: a multicenter experience. Surg Obes Relat Dis 14(5):594–601. https://doi.org/10.1016/j.soard.2018.01.020
9. Zaveri H, Surve A, Cottam D, Cottam A, Medlin W, Richards C, Belnap L, Cottam S, Horsley B (2018) Mid-term 4-year outcomes with single anastomosis duodenal-jejunal bypass with sleeve gastrectomy surgery at a single US center. Obes Surg 28(10):3062–3072. https://doi.org/10.1007/s11695-018-3358-x
10. Moon RC, Gaskins L, Teixeira AF, Jawad MA (2018) Safety and effectiveness of single-anastomosis duodenal switch procedure: 2-year result from a single US institution. Obes Surg 28(6):1571–1577. https://doi.org/10.1007/s11695-017-3066-y
11. Sánchez-Pernaute A, Rubio MA, Cabrerizo L, Ramos-Levi A, Pérez-Aguirre E, Torres A (2015) Single-anastomosis duodenoejejunal bypass with sleeve gastrectomy (SADI-S) for obese diabetic patients. Surg Obes Relat Dis 11(5):1092–1098. https://doi.org/10.1016/j.soard.2015.01.024
12. Praveen Raj P, Kumaravel R, Chandramaliteswaran C, Rajpandian S, Palaniivelu C (2012) Is laparoscopic duodenojejunal bypass with sleeve an effective alternative to Roux en Y gastric bypass in morbidly obese patients: preliminary results of a randomized trial. Obes Surg 22(3):421–426. https://doi.org/10.1007/s11695-011-0507-x
13. Roehlen N, Laubner K, Betterding D, Schwacha H, Hilger H, Koenig C, Grueninger D, Krebs A, Seufert J (2020) Duodenal-jejunal bypass liner (DJBL) improves cardiovascular risk biomarkers and predicted 4-year risk of major CV events in patients with type 2 diabetes and metabolic syndrome. Obes Surg 30(4):1200–1210. https://doi.org/10.1007/s11695-019-04324-2
14. Homan M, Kovač J, Orel R, Battelino T, Kotnik P (2020) Relevant weight reduction and reversed metabolic co-morbidities can be achieved by duodenojejunal bypass liner in adolescents with morbid obesity. Obes Surg 30(3):1001–1010. https://doi.org/10.1007/s11695-019-04279-4
15. Deutsch L, Ben Haim, Sofer Y, Gluck N, Santo E, Fishman S (2018) Long-term effects of proximal small bowel exclusion by duodenal-jejunal bypass liner on weight reduction and glycemic control in diabetic patients. Surg Obes Relat Dis 14(10):1561–1569. https://doi.org/10.1016/j.soard.2018.07.022
16. Laubner K, Riedel N, Fink K, Holl RW, Welp R, Kempe HP, Lautenbach A, Schlensak M, Stengel R, Eberl T, Dederichs F, Schwacha H, Seufert J, Aberle J (2018) Comparative efficacy and safety of the duodenal-jejunal bypass liner in obese patients with type 2 diabetes mellitus: a case control study. Diabetes Obes Metab 20(8):1868–1877. https://doi.org/10.1111/dob.13300
17. Patel N, Mohanaruban A, Ashrafian H, Le Roux C, Byrne J, Mason J, Hopkins J, Kelly J, Teare J (2018) EndoBarrier®: a safe and effective novel treatment for obesity and type 2 diabetes? Obes Surg 28(7):1980–1986. https://doi.org/10.1007/s11695-018-3123-1
18. Riedel N, Laubner K, Lautenbach A, Schön G, Schlensak M, Stengel R, Eberl T, Dederichs F, Aberle J, Seufert J (2018) Longitudinal evaluation of efficacy, safety and nutritional status during one-year treatment with the duodenal-jejunal bypass liner. Surg Obes Relat Dis 14(6):769–779. https://doi.org/10.1016/j.soard.2018.02.029
19. Quezada N, Muñoz R, Morelli C, Turiel D, Hernández J, Pimentel F, Escalona A (2018) Safety and efficacy of the endoscopic duodenal-jejunal bypass liner prototype in severe or morbidly obese subjects implanted for up to 3 years. Surg Endosc 32(10):3306–3313. https://doi.org/10.1007/s11695-017-3083-1
20. Straubmann B, Krepak Y, Schlifer E, Jarick I, Hauber M, Lee-Barkey YH, Fischer M, Tschope D (2016) Beneficial metabolic effects of duodenal jejunal bypass liner for the treatment of adipose patients with type 2 diabetes mellitus: analysis of responders and non-responders. Horm Metab Res 48(10):630–637. https://doi.org/10.1055/s-0042-1715175
21. Muñoz R, Domínguez A, Muñoz F, Muñoz C, Sláko M, Turiel D, Pimentel F, Sharp A, Escalona A (2014) Baseline glycated hemoglobin levels are associated with duodenal-jejunal bypass liner-
induced weight loss in obese patients. Surg Endosc 28(4):1056–1062. https://doi.org/10.1007/s00464-013-3283-y

23. de Moura EG, Martins BC, Lopes GS, Orso IR, de Oliveira SL, Galvão Neto MP, Santo MA, Sakai P, Ramos AC, Garrido Júnior AB, Mancini MC, Halpem A, Cecconello I (2012) Metabolic improvements in obese type 2 diabetes subjects implanted for 1 year with an endoscopically deployed duodenal-jejunal bypass liner. Diabetes Technol Ther 14(2):183–189. https://doi.org/10.1089/ dia.2011.0152

24. Furuya-Kanamori L, Barendregt JJ, Doi SAR (2018) A new improved methodical and quantitative method for detecting bias in meta-analysis. Int J Evid Based Healthcare 16(4):195–203. https://doi.org/10.1097/XEB.0000000000000141

25. Doi SA, Barendregt JJ, Khan S, Thalib L, Williams GM (2015) Advances in the meta-analysis of heterogeneous clinical trials I: The inverse variance heterogeneity model. Contemp Clin Trials 45(Pt A):130–138. https://doi.org/10.1016/j.cct.2015.05.009

26. Doi SA, Barendregt JJ, Khan S, Thalib L, Williams GM (2015) Advances in the meta-analysis of heterogeneous clinical trials II: The quality effects model. Contemp Clin Trials 45(Pt A):123–129. https://doi.org/10.1016/j.cct.2015.05.010

27. Doi SA, Barendregt JJ, Khan S, Thalib L, Williams GM (2014) An updated method for risk adjustment in outcomes research. Value Health 17(5):629–633. https://doi.org/10.1016/j.jval.2014.05.003

28. Dindo D, Demartines N, Clavien PA (2004) Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 240(2):205–216. https://doi.org/10.1097/01.sla.0000133083.54934.ae

29. Sethi P, Thillai M, Nain PS, Ahuja A, Aulakh N, Khurana P (2018) Jejunoileal bypass changes the duodenal cholecystokinin and so- matostatin cell density. Obes Surg 13(4):584–590. https://doi.org/10.1381/0960892032322190781

30. Clavien PA, Barkun J, de Oliveira ML, Vauthey JN, Dindo D, Schulick RD, de Santibañes E, Pekolj J, Slankamenac K, Bassi C, Graf R, Vonlanthen R, Padbury R, Cameron JL, Makuuchi M (2009) The Clavien-Dindo classification of surgical complications: five-year experience. Ann Surg 250(2):187–196. https://doi.org/10.1097/SLA.0b013e3181b13ca2

31. Arterburn DE, Telem DA, Kushner RF, Courcoulas AP (2020) Benefits and risks of bariatric surgery in adults: a review. JAMA 324(9):879–887. https://doi.org/10.1001/jama.2020.12567

32. Jejunoileal bypass changes the duodenal cholecystokinin and so- matostatin cell density. Obes Surg 13(4):584–590. https://doi.org/10.1381/0960892032322190781

33. Steinert RE, Feinle-Bisset C, Asarian L, Horowitz M, Beglinger C, Geary N (2017) Ghrelin, CCK, GLP-1, and PYY(3-36): Secretory controls and physiological roles in eating and glycemia in health, obesity, and after RYGB. Physiol Rev 97(1):411–463. https://doi.org/10.1152/physrev.00031.2014

34. Santoro S (2012) Stomachs: does the size matter? Aspects of intestinal satiety, gastric satiety, hunger and gluttony. Clinics (Sao Paulo) 67(4):301–303

35. Ruban A, Ashrafian H, Teare JP (2018) The EndoBarrier: duodenal-jejunal bypass liner for diabetes and weight loss. Gastroenterol Res Pract 2018:7823182. https://doi.org/10.1155/2018/7823182 eCollection 2018 Review

36. Sethi P, Thillai M, Nain PS, Ahuja A, Aulakh N, Khurana P (2018) Jejunoileal bypass changes the duodenal cholecystokinin and so- matostatin cell density. Obes Surg 13(4):584–590. https://doi.org/10.1381/0960892032322190781

Publisher’s note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.