Direct percutaneous endoscopic jejunostomy (DPEJ) and percutaneous endoscopic gastrostomy with jejunal extension (PEG-J) technical success and outcomes: Systematic review and meta-analysis

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ABSTRACT

Background and study aims Endoscopic methods of delivering uninterrupted feeding to the jejunum include direct percutaneous endoscopic jejunostomy (DPEJ) or PEG with jejunal extension (PEG-J), validated from small individual studies. We aim to perform a meta-analysis to assess their effectiveness and safety in a variety of clinical scenarios.
Methods Major databases were searched until June 2021. Efficacy outcomes included technical and clinical success, while safety outcomes included adverse events (AEs) and malfunction rates. We assessed heterogeneity using I^2 and classic fail-safe to assess bias.
Results 29 studies included 1874 patients (983 males and 809 females); mean age of 60 ± 19 years. Pooled technical and clinical success rates with DPEJ were 86.6 % (CI, 82.1–90.1, I^2 73.1) and 96.9 % (CI, 95.0–98.0, I^2 12.7). The pooled incidence of malfunction, major and minor AEs with DPEJ were 11 %, 5 %, and 15 %. Pooled technical and clinical success for PEG-J were 94.4 % (CI, 85.5–97.9, I^2 33) and 98.7 % (CI, 95.5–99.6, I^2 < 0.001). The pooled incidence of malfunction, major and minor AEs with DPEJ were 24 %, 1 %, and 25 %. Device-assisted DPEJ performed better in altered gastrointestinal anatomy. First and second attempts were 87.6 % and 90.2 %.
Conclusions DPEJ and PEG-J are safe and effective procedures placed with high fidelity with comparable outcomes. DPEJ was associated with fewer tube malfunction and failure rates; however, it is technically more complex and not standardized, while PEG-J had higher placement rates. The use of balloon enteroscopy was found to enhance DPEJ performance.

Introduction

Background

Malnutrition, swallowing disturbances, and prolonged weight loss negatively impact the body, contributing to poor functional and clinical outcomes. They are significant causes of morbidity and mortality in patients with advanced diseases, and nutritional supplementation remains the cornerstone to maintain daily requirements. There has been a paradigm shift in the approach to nutrition, traditionally seen as an adjunct; it has bonafide therapeutic benefits by attenuating immune and host responses. Enteral nutrition has demonstrated better clinical outcomes, reduced infection risk, and cost efficiency than parenteral nutrition; hence it is considered the preferred method to deliver nutrition in a patient with a functional gastrointestinal system [1–3]. Among various jejunal strategies, endoscopic guided techniques, PEG with a jejunal extension (PEG-J) and direct percutaneous endoscopic jejunostomy (DPEJ) have shown superior results to nasojejunal or parental feeding [3]. Additionally, compared to surgical options, endoscopic guided procedures have less exposure to anesthesia, rapid recovery times, lower costs, and can benefit a variety of patients with complicated GI anatomy (previous Billroth II, Roux-en-Y, bariatric, bowel resection, or pancreatic reconstruction), gastric atony, or gastrointestinal obstruction [4].

The indication for enteral feeding tubes are patients with a functioning gastrointestinal tract unable to meet their oral caloric intake for long-term nutrition [5]. The goal is to deliver feeds deep into the jejunum; the mean distance in one study was 70 cm (60cm–90 cm) past pylorus or anastomosis. Recent studies looking at nutritional support in these patients have shown reduced rates of pneumonia and increased nutrition delivery in post-pyloric feeding with minimal significant adverse events and safe insertion mechanisms. However, the best method of jejunal feeding remains unclear due to insufficient evidence. PEG-J are placed through an existing gastrostomy, and various placement methods have been described, either transorally or through the gastrostomy tract. The jejunal tube that serves as an extension to the PEG tube measures 9 Fr to 12 Fr in diameter, roughly 60 cm in length, and is typically dragged into the jejunum by endoscopic forceps or fluoroscopically. In contrast, DPEJ includes positioning an enteroscope or pediatric colonoscope into the jejunum and inserting the tube via direct puncture of the jejunum [6]. In addition, several studies have used balloon-assisted enteroscopy (single or double) along with fluoroscopy to augment dexterity and success rates [7–9].

The American Society for Gastrointestinal Endoscopy (ASGE) and the European Society of Gastrointestinal Endoscopy (ESGE) support PEG-J and DPEJ as alternatives in patients that require long-term post-pyloric feeding. However, the lack of convincing clinical evidence has important implications for patients and gastroenterologists alike and has limited its adoption [7, 10–12]. The evolving demand for jejunal feeding necessitates a review looking at its success and complication rates. Therefore, we conducted a systematic review and meta-analysis to test our hypothesis and assess the success and safety factors of DPEJ and PEG-J in jejunal feeding.

Material and methods

Protocol and registration

This review has been in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses Statement (PRISMA) and Meta-analyses of Observational Studies in Epidemiology (MOOSE) reporting standards (**Supplementary Table 1** and **Supplementary Table 2**) [13, 14].

Eligibility criteria, literature search, and search strategy

An expert librarian conducted a systematic literature search using a priori protocol to identify studies enrolling patients that received a direct percutaneous endoscopic jejunostomy (DPEJ) or percutaneous endoscopic gastrostomy with a jejunal extension (PEG-J). The search strategies included “direct percutaneous endoscopic jejunostomy,” “percutaneous endoscopic gastrostomy,” “PEJ,” “PEG-J,” “EPJ,” and “jejunal feeding” with Boolean operators. The search was run in June 2021 across multiple databases, including Ovid EBM Reviews, Ovid Embase (1974 +), Ovid Medline (1946 + including epub ahead of print, in-process, and other non-indexed citations), Scopus (1970 +), Web of Science (1975 +), and PubMed. The search was restricted to articles in English and identified searches were exported to a reference manager (EndNote) to filter duplicates. We cross-checked the reference lists of identified sources for additional relevant studies, including the grey literature. Any discrepancy was resolved by a third reviewer (SD). Complete search strategy can be found in **Supplementary Table 3**. Conference abstracts were excluded due to a lack of usable data.

Study selection

This meta-analysis included studies that evaluated the outcomes of jejunal feeding strategies for nutritional support, specifically studies with primary direct PEJ (DPEJ) or gastrostomy with jejunal extension tubes (PEG-J). Studies reporting surgical jejunal feeding strategies, performance in pediatric age groups (< 18 years), and non-English studies were excluded. Studies were restricted to full-text manuscripts as we considered abstracts to have insufficient information and high bias to be included in our assessment. Two authors decided on the final selection (SD, SC).

Data abstraction and quality assessment

Two reviewers (AP, MH) independently extracted eligible information into an a priori designed Google Excel sheet. The Qumseya scale for quality assessment of cohort studies for systematic reviews and meta-analyses consisted of nine questions [15]. We assessed each study for its design, measurements, outcomes, and patient characteristics. Each risk of bias was judged on a maximum score of 10. Studies with less than six were considered low, 6 to 7 were moderate, and >8 were considered high quality [15].

Outcomes assessed

Efficacy outcomes

Technical success was defined as the ability to successfully insert a feeding tube into the proximal jejunum by DPEJ or PEG-J. Overall technical success (placement rate) for either procedure was successful attempts/total attempts [5–7, 11, 12]. Clinical success was the effective use of a jejunal tube for feeding patients in whom TS was achieved with water or enteral feed delivered into the small intestine within 24 hours [5–7, 11, 12].

Safety outcomes

Complications and adverse events were categorized into "malfunction," "major," and "minor." Malfunction included dislodgement, displacement, peristomal leakage, kinking, clogging, or buried bumper syndrome. Major adverse events included any adverse event that required endoscopic, surgical, or radiological intervention after achieving clinical success. Minor was defined by insertion site infections, fever, abdominal pain, or controlled bleeding. Peristomal infection was defined as observed local inflammatory signs such as erythema, induration, and exudate with pain or tenderness. Ease of endoscopic placement was assessed by the number of attempts to place a jejunal feeding tube.

Statistical analysis

Statistical analysis was performed using Comprehensive Meta-Analysis (CMA 3.0) software (Biostat, Englewood, New Jersey, United States). Pooled estimates and corresponding 95 % confidence intervals (CI) for dichotomous variables were calculated using the random-effects inverse variance/DerSimonian-Laird method [16].

Heterogeneity was measured by Cochrane Q and I^2 statistics, with values of < 30 %, 31 % to 60 %, 61 % to 75 %, and > 75 % suggesting low, moderate, substantial, and considerable heterogeneity, respectively [17, 18]. A funnel plot combined with Egger's tests was performed to assess publication bias. $P \le 0.05$ combined with asymmetry in the funnel plots was used to measure significant publication bias, and if < 0.05, the trim-and-fill computation was used to evaluate the effect of publication bias on the interpretation of the results. We additionally calculate the prediction intervals using the CMA software. Three levels of impact were reported based on the concordance between the reported results and the actual estimate if there was no bias. The impact was reported as minimal if both versions were estimated to be the same, modest if the effect size changed substantially, but the final finding would remain the same and severe if the bias threatens the conclusion of the analysis [19]. Sensitivity analysis to evaluate an individual study's effect on the collective outcome was completed. We also explored heterogeneity through meta-regression from continuous variable modifiers and subgroup analysis from dichotomous variable modifiers.

Results

Study characteristics

An initial search identified 451 studies. After screening 67 full-text articles, 29 studies were eligible for qualitative and quantitative synthesis. All studies assessed successful placement and adverse effects. Study locations included Australia, Belgium, Italy, Germany, Netherlands, Portugal, the United States, and the United Kingdom. Variations in the type of jejunal feeding were seen; five used PEG-J and 24 used DPEJ. Five DPEJ studies used device-assisted enteroscopy (single-balloon two and double-balloon three). Among 29 studies, 1874 patients (983 males and 803 females); were included, with the mean age 60 ± 19 years and BMI 23.1 ± 5.5. The mean procedure duration was 45.2 ± 34.1 min, with longer times in unsuccessful attempts, altered anatomy, and patients with a BMI > 25. The mean follow-up duration of endoscopically placed jejunal feeding was 530 ± 517 days, while the mean time to tube malfunction was 162 ± 135 days. The mean weight gain was 4.6 ± 4.4kg. Study and baseline clinical characteristics have been summarized in ▶ **Table 1**, ▶ **Table 2**, and ▶ **Table 3**.

Quality assessment

Scores for methodological quality assessment are shown in Supplementary ▶ **Fig. 1**. Five studies were adjudged as low quality [20–24], 16 as moderate quality [25–40], and eight as high quality [41–48]. Among 29 studies, 11 were prospective [44, 46, 47, 20–22, 28, 41–43, 29] and 18 were retrospective [23–27, 30–40, 45, 48]. Two studies were multi-centered [45, 48].

Meta-analysis outcomes

We evaluated procedural and safety outcomes for DPEJ and PEG-J. Technical success (TS): DPEJ – 22 studies, 1614 patients with a pooled TS of 86.6 % (CI, 82.1–90.1, I^2 73.1 %), while PEG-J – three studies, 138 patients had a pooled TS of 94.4 % (CI, 85.5–97.9, I^2 33.0 %). The difference between both was not statistically significant, p = 0.09 (▶ **Fig. 1**). The true effect size in 95 % of all comparable populations falls in the interval 0.65–0.96 (DPEJ) and 0.00–1.00 (PEG-J).

Clinical success (CS): DPEJ – 24 studies, 1413 patients with a pooled CS of 96.9 % (CI, 95.0–98.0, I^2 12.7 %), while PEG-J – five studies, 241 patients had a pooled CS of 98.7 % (CI, 95.5–99.6, I^2 < 0.001 %). The difference between both was not statistically significant, $P = 0.2$ (▶ **Fig. 2**). The true effect size in 95 % of all comparable populations falls in the interval 0.92–0.99 (DPEJ) and a common effect size within the PEG-J group.

Malfunction: DPEJ – 24 studies, 1364 patients had a pooled malfunction rate of 10.8 % (CI, 7.0–1.6 %, I^2 77.8 %), while PEG-J – five studies, 241 patients had a pooled malfunction rate of 23.6 % (CI, 7.5 %–54.1 %, I^2 90.8 %). The difference between both was not statistically significant, $P = 0.2$ (▶ **Fig. 3**). The true effect size in 95 % of all comparable populations falls in the interval 0.02–0.44 (DPEJ) and 0.00–0.97 (PEG-J).

Major adverse events: DPEJ – 24 studies, 1417 patients had a pooled major adverse events rate of 5.0 % (CI, 3.3–7.6, I^2 49.4%), while PEG-J – five studies, 241 patients had a pooled

▶ **Table 1** Study procedure characteristics.

Author/Year	Design	Total patients (*n*)	Procedure type	Endoscope manufacturer	Reported technique	Use of Fluoroscopy	Anesthesia Used	Peri-procedural antibiotics	Tube manufacturer	Size of the tube (PEG, PEG-J, and DPEJ)	Mechanisms for unsuccessful placement	Procedure time – minutes (mean ± SD)
Ponsky 1984 [20]	Prospective, single-center, < 1984, USA	10	PEG-J	N/A	Modified Gauderer and Ponsky technique	No	Local anesthesia/sedation	N/A	N/A	16 or 18-Fr PEG tube	None	N/A
Shike 1987 [21]	Prospective, single-center, < 1987, USA	11	DPEJ	N/A	Modified Gauderer and Ponsky technique	No	Local anesthesia/Sedation	N/A	N/A	N/A	▪ No transillumination (2)	N/A
Kaplan 1989 [22]	Prospective, single-center, Jan 1985 – Dec 1987, USA	23	PEG-J	N/A	Modified Gauderer and Ponsky technique	No	Local anesthesia with sedation (22) General anesthesia (1)	Yes Cefazolin 1 gm IV prior to procedure	N/A	18-Fr PEG tube with 9-Fr J-tube	None	N/A
Shike 1991 [41]	Prospective, single-center, < 1991, USA	6	DPEJ	N/A	Shike modification	No	Local anesthesia	Yes Cefazolin 1 gm IV prior to procedure	N/A	N/A	▪ No transillumination (3)	N/A
Mellert 1993 [42]	Prospective, single-center, Jan 1990 – Jun 1992, Germany	44	DPEJ	200-cm-long endoscope (Fujinon EN7-MR2)	Modified Gauder and Ponsky technique	No	Local anesthesia/Sedation	Yes Mezlocillin 2 gm before procedure	PEG kit (PEG Universal Intestinal, Fresenius, FRG)	N/A	▪ No transillumination (3) ▪ Inability to pass an endoscope into the jejunum (2)	N/A
Shike 1996 [43]	Prospective, single-center, < 1996, USA	150	DPEJ	N/A	Modified Gauderer and Ponsky technique	No	Local anesthesia/Sedation	Yes Cefazolin 1 gm IV prior to procedure	PEG kit (Sandoz Nutrition, Minneapolis, Minn.)	14 to 28-Fr	▪ Inability to pass endoscope due to anatomy ▪ No transillumination	N/A

▶ **Table 1** (Continuation)

Author/Year	Design	Total patients (*n*)	Procedure type	Endoscope manufacturer	Reported technique	Use of Fluoroscopy	Anesthesia Used	Peri-procedural antibiotics	Tube manufacturer	Size of the tube (PEG, PEG-J, and DPEJ)	Mechanisms for unsuccessful placement	Procedure time – minutes (mean ± SD)
Rumalla 2000 [23]	Retrospective, single center, Oct 1998 – Jan 2000, USA	36	DPEJ	Pediatric colonoscope (Olympus PCF, Olympus America Inc, Melville, NY) or push enteroscopy (Olympus SIF-IOO)	Shike modification	No	Local anesthesia	N/A	PEG tube (MIC PEG, Ballard Medical Products, Draper, Utah)	20-Fr PEG tube	▪ No transillumination (8) ▪ Small bowel stricturing (2)	N/A
Barrera 2001 [26]	Retrospective, single-center, 28 months, USA	17	DPEJ	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Shetzline 2001 [28]	Prospective, single-center, < 2001, USA	7	DPEJ	Push enteroscope (VSB 3430, Pentax, Orangeburg, NY)	Modified Gauderer and Ponsky technique	Yes	Local anesthesia	Yes	PEG tube (standard kit, Bard Interventional Products, Billerica, Mass)	20-Fr PEG tube	▪ Inability to pass needle (1)	40.7 ± 14
Varadarajulu 2003 [44]	Prospective, single-center, consecutive, Jan 2000 – Dec 2001, USA	26	DPEJ	N/A	Standard Pull technique	No	Local anesthesia	Yes Cefazolin 1 gm IV prior to procedure	Pull-type PEG kit (Microvasive Endoscopy, Boston Scientific Corp., Nztick, Mass)	24-Fr PEG tube (24) 20-Fr PEG tube (2)	▪ No transillumination (1) ▪ Small bowel perforation (1)	23.3 ± 16.1
Bueno JT 2003 [27]	Retrospective, single-center, February 1996–2001, USA	25	DPEJ	N/A	Shike modification	No	N/A	Yes Cefazolin or Clindamycin	N/A	20-Fr PEG tube	▪ No transillumination (3) ▪ Inability to pass endoscope due to anatomy (1)	N/A

▶ **Table 1** (Continuation)

Author/Year	Design	Total pa-tients (*n*)	Proce-dure type	Endoscope manufac-turer	Reported technique	Use of Fluor-oscopy	Anesthesia Used	Peri-proce-dural anti-biotics	Tube manu-facturer	Size of the tube (PEG, PEG-J, and DPEJ)	Mechanisms for unsuc-cessful place-ment	Proce-dure time – minutes (mean ± SD)
Maple 2005 [45]	Retrospec-tive, multi-center, con-secutive, January 1996 – Au-gust 2004, USA	286	DPEJ	N/A	Modified Gauder and Ponsky technique	No	Local anes-thesia/Se-dation	Yes Cefazolin 1 gm IV	PEG tube kit (Kimberly-Clark/Ballard Medical Pro-ducts, Draper, UT)	20-Fr PEG tube	▪ No transil-lumination/finger in-dentation (79) ▪ Inability to pass scope to the jeju-num (8) ▪ Difficulty passing scope and no transil-lumination (6) ▪ Adverse re-sponse to sedation (4) ▪ Equipment failure (1)	N/A
Del Piano M 2008 [29]	Prospective, single cen-ter, conse-cutive, April 2003 – March 2004, USA	9	DPEJ	Pediatric video colo-noscope (Olympus PCF-160 AL, Olympus Medical Sys-tem Corp., Tokyo, Ja-pan)	Pull tech-nique	No	N/A	N/A	PEG tube kit (Kimberly Clark, Ballard Medical Pro-ducts, Draper, Utah, USA)	18 to 20-Fr PEG tube	▪ No transil-lumination	20

▶ **Table 1** (Continuation)

Author/Year	Design	Total patients (*n*)	Procedure type	Endoscope manufacturer	Reported technique	Use of Fluoroscopy	Anesthesia Used	Peri-procedural antibiotics	Tube manufacturer	Size of the tube (PEG, PEG-J, and DPEJ)	Mechanisms for unsuccessful placement	Procedure time – minutes (mean ± SD)
Mackenzie 2008 [30]	Retrospective, single-center, consecutive, February 2000 – September 2005, USA	75	DPEJ	N/A	Modified Gauder and Ponsky technique	No	N/A	Yes Cefazolin 1 gm IV	PEG tube kit (EndoVive; Microvasive Endoscopy, Boston Scientific Corp, Natick, Mass)	20-Fr PEG tube	▪ No trasnillumination	BMI > 25: 40 ± 25.8 BMI < 25: 37 ± 18.1
Panagiotakis 2008 [31]	Retrospective, single-center, 1999–2005, USA	11	DPEJ	N/A	Shike modification	No	N/A	N/A	PEG kit (Boston Scientific, Natick, MA).	20-Fr PEG tube	None	
Moran 2009 [32]	Retrospective, single-center, consecutive, January 2002 – April 2008, United Kingdom	40	DPEJ	N/A	Shike modification	Yes	Sedation (35) General anesthesia (5)	Yes Co-amoxiclav 2.2 gm	Fresenius PEG kit	15-Fr PEG	▪ Inability to access the jejunum safely	20.8 ± 4.1
Aktas 2012 [33]	Case-series, single-center, consecutive, December 2009 – December 2010, Netherlands	11	SBE-DPEJ	Olympus SIF-Q160Y enteroscopy (Olympus, Tokyo, Japan)	Shike modification	No	Sedation/ General anesthesia	Yes	PEG feeding tube (Fresenius Kabi AG, Germany)	15-Fr PEG	▪ Inadequate insertion of the enteroscope into the jejunum	47 ± 33.5

▶ Table 1 (Continuation)

Author/Year	Design	Total patients (*n*)	Procedure type	Endoscope manufacturer	Reported technique	Use of Fluoroscopy	Anesthesia Used	Peri-procedural antibiotics	Tube manufacturer	Size of the tube (PEG, PEG-J, and DPEJ)	Mechanisms for unsuccessful placement	Procedure time – minutes (mean ± SD)
Song 2012 [46]	Prospective, single-center, USA	10	DBE-DPEJ	Pediatric colonoscopes (PCF-Q180AL, Olympus, America, Center Valley, PA)	Standard Pull technique	Yes, if altered gut	Sedation/ General anesthesia	N/A	PEG kit (MIC PEG Kit, Kimberly-Clark, Roswell, GA)	20-Fr feeding tube	None	29 ± 12..2
Toussaint 2012 [34]	Case series, single-center, consecutive, October 2008 – May 2011, Belgium	12	DPEJ	Enteroscopy (SIF-100; Olympus Optical Co. [Europa], Hamburg, Germany)	Shike modification	N/A	General anesthesia	Yes Cefazolin 2 gm, ciprofloxacin 4 gm, or amoxicillin 2 gm before the procedure	Tube (Flocare Nutricia, Nutricia Medical Devices, Schiphol, The Netherlands)	18-Fr feeding tube	▪ No transillumination (3)	N/A
Lim 2015 [47]	Prospective, single-center, 2003–2012, Australia	83	DPEJ	Pediatric colonoscope (Olympus PCF 160AL)	N/A	N/A	Local anesthesia	N/A	MIC PEG kit (Kimberly-Clark, Roswell, GA 30076, USA).	20-Fr PEG tube	▪ Lack of transillumination (7) ▪ Altered anatomy with large hiatus hernia or intrathoracic stomach	N/A
Velázquez-Aviña 2015 [35]	Retrospective, single center, Jan 2013 – Mar 2014, USA	25	SBE-DPEJ	Double-balloon enteroscope (Fujinon EN-450T5, Fuji; Fujifilm, Saitama, Japan) used in single-balloon mode	Modified Gauder and Ponsky technique	Yes	General Anesthesia	Yes Cefazolin 2 gm IV before procedure	PEG-kit (Cook, Winston Salem, NC, USA)	20-Fr PEG tube	▪ No transillumination (1)	30.5 ± 10

▶ **Table 1** (Continuation)

Author/Year	Design	Total patients (n)	Procedure type	Endoscope manufacturer	Reported technique	Use of Fluoroscopy	Anesthesia Used	Peri-procedural antibiotics	Tube manufacturer	Size of the tube (PEG, PEG-J, and DPEJ)	Mechanisms for unsuccessful placement	Procedure time – minutes (mean ± SD)
Al-Bawardy 2016 [36]	Retrospective, single-center, single-center, July 2010 – November 2013, USA	94	DBE-DPEJ	Double-balloon enteroscope with a large working channel (EN-450T5; Fujinon, Inc., Saitama, Japan)	Modified Gauder and Ponsky technique	Yes, if altered gut	General anesthesia/Sedation	Yes Cefazolin	PEG kit (MIC-KEY gastrostomy tube; Halyard, Alpharetta, Georgia, USA)	20-Fr PEG tube	Native Gut (3): ▪ inability to advance overtube ▪ inability to advance the instrument due to anatomy ▪ no transillumination Altered Gut (4): ▪ small bowel fixation/angulations due to adhesions	▪ Native Gut: 31 ± 18 ▪ Altered Gut: 33 ± 20
Bernardes 2017 [37]	Retrospective, single-center, January 2010 – February 2016, USA	23	SBE-DPEJ	SIF-Q180 enteroscope (Olympus, Tokyo, Japan),	Modified Gauder and Ponsky technique	No	Sedation	Yes 1 gm IV ceftriaxone before the procedure	N/A	20-Fr	▪ Inadequate transillumination (3) ▪ Jejunal perforation during the procedure (1)	N/A
Strong 2017 [24]	Retrospective, single center, May 1, 2003 – June 30, 2015, USA	59	DPEJ	N/A	Modified Gauder and Ponsky technique	N/A	▪ General anrsthesia (27) ▪ Sedation (27)	Yes	N/A	▪ 10-Fr (1) ▪ 16-Fr (8) ▪ 18-Fr (2) ▪ 20-Fr (41)	None	23 ± 10

▶ Table 1 (Continuation)

Author/Year	Design	Total patients (n)	Procedure type	Endoscope manufacturer	Reported technique	Use of Fluoroscopy	Anesthesia Used	Peri-procedural antibiotics	Tube manufacturer	Size of the tube (PEG, PEG-J, and DPEJ)	Mechanisms for unsuccessful placement	Procedure time – minutes (mean ± SD)
Kirstein 2018 [39]	Retrospective, single-center, 2009–2015, Germany	39	PEG-J	N/A	Modified Gauder and Ponsky technique	N/A	General anesthesia/ Sedation	Yes	N/A	N/A	N/A	27.7 ± 6.1
Ridtitid 2018 [38]	Retrospective, single-center, Jul 2010 – Jun 2012, USA	102	PEG-J	N/A	Modified Gauder and Ponsky technique	Yes	N/A	N/A	PEG tube (EndoVive Safety; Boston Scientific, Natick, Mass)	24-Fr PEG tube with 12-Fr J-tube	▪ No transillumination ▪ Inability to identify satisfactory location for insertion	N/A
Simoes 2018 [40]	Retrospective, single-center, January 2009 – March 2015, USA	452	DPEJ	Pediatric colonoscope or an adult esophagogastroduodenoscope	Shike modification	N/A	N/A	N/A		20-Fr PEG tube	▪ Inadequate transillumination ▪ Stenosis preventing passage of enteroscope ▪ Inability to localize appropriate spot for tube placement ▪ Extrinsic compression	Successful 60.7 ± 38.6 Non-successful 71.4 ± 37.8

▶ **Table 1** (Continuation)

Author/Year	Design	Total patients (*n*)	Procedure type	Endoscope manufacturer	Reported technique	Use of Fluoroscopy	Anesthesia Used	Peri-procedural antibiotics	Tube manufacturer	Size of the tube (PEG, PEG-J, and DPEJ)	Mechanisms for unsuccessful placement	Procedure time – minutes (mean ± SD)
Cococcia 2020 [25]	Retrospective, single-center, Mar 2010 – Mar 2020, Italy	73	PEG-J	N/A	Standard Pull technique	N/A	N/A	N/A	AbbVie 15 Fr or 20 Fr (AbbVie Inc., North Chicago, IL, USA) Boston Scientific 20 Fr tube TTP J-Tube (Boston Scientific Corporation, Natick, MA, USA).	▪ 15-Fr with 9-Fr J-tube (7) ▪ 20-Fr with 9-Fr J-tube (30) ▪ 20-Fr with 8.5-Fr J-tube (36)	N/A	N/A
Nishiwaki 2021 [48]	Retrospective, Multicenter, consecutive, April 2004 – March 2019, USA	115	DPEJ	Enteroscopy (SIF Q240 or SIF Q260, Olympus Medical Co, Tokyo, Japan)	Standard Pull technique	Yes	N/A	Yes 3 days post-placement	PEG button kit (One Step Button, Boston Scientific Co, Natick, Mass, USA) Safety PEG kit (Standard PEG system, Ponsky PEG, Bard Access Systems, Inc, Salt Lake City, Utah, USA).	N/A	▪ Failure of transillumination (5) ▪ Technical failure (2)	25.4 ± 12.7

BMI, body mass index; cal, calories; CVA, cerberocascular accident; DPEJ, direct percutaneous endoscopic jejunostomy; Fr, French; GI, gastrointestinal; IV, intravenous; J-tube,jJejunostomy tube; N/A, not applicable; PEG, percutaneous endoscopic gastrostomy; PEJ, percutaneous endoscopic jejunostomy; PEG-J, jejunal extension through PEG; SD, standard deviation.

▶ **Table 2** Study safety characteristics.

Author/ Year	Mechanisms for failure after initiating feeds	Major adverse event – All-cause mortality	Major adverse event requiring intervention – surgery or repeat endoscopy	Minor adverse events	Short term (<30 days)	Long term (>30 days)
Ponsky 1984 [20]	None	None	None	None	None	None
Shike 1987 [21]	N/A	N/A	None	▪ Localized peristomal infection (1) ▪ Partial small bowel obstruction distal to PEJ with leakage (1)	▪ Leakage of fluid with partial small bowel obstruction (1) ▪ Localized peristomal infection (1)	N/A
Kaplan 1989 [22]	N/A	11 deaths	▪ Detachment/clogging of the tubes (22)	▪ Aspiration pneumonia (3) ▪ Upper GI Bleed (7)	▪ Aspiration pneumonia (3) ▪ Detachment/clogging of the tube ▪ Upper GI Bleed	▪ Clogging/detachment of the tubes
Shike 1991 [41]	N/A	None	None	▪ Post procedure fever (1)	▪ Fever (1)	None
Mellert 1993 [42]	None	None	▪ Tube dysfunction/breakage (5) ▪ Jejunal ulcer (1)	▪ Jejunal ulcer (1) ▪ Local wound infection (3)	▪ Jejunal ulcer (2) ▪ Wound infection (3) ▪ Tube dyssfunction/breakage	▪ Tube dysfunctin/breakge
Shike 1996 [43]	None	One death from complication 62 death entire f/u	▪ Severe gastric bleeding (1) ▪ Abdominal wall abscess (1) ▪ Colonic perforation (1) ▪ Tube malfunction (3)	▪ Procedural hypoxemia/hypotension (6) ▪ Infection (9) ▪ Leakage around the tube (12) ▪ Aspiration (3)	▪ Procedural hypoxemia/hypotension (6) ▪ Infection (9) ▪ Gastric bleeding (1) ▪ Abdominal wall abscess (1) ▪ Colonic perforation (1)	▪ Tube malfunction (3) ▪ Leakage around the tube (12) ▪ Aspiration (3)
Rumalla 2000 [23]	N/A	N/A	▪ Bowel obstruction and volvulus (1) ▪ Persistent enterocutaneous fistula after tube removal (2)	▪ Tube site pain (13) ▪ Site drainage (12)	▪ Bowel Obstruction and volvulus (1)	▪ Persistent enterocutaneous fistula after removal of tube (2)
Barrera 2001 [26]	N/A	3 deaths from primary disease	▪ Colonic perforation with peritonitis (1)	▪ Persistent ileus (1)	None	None
Shetzline 2001 [28]	None	1 from infection		▪ Infection (1)	▪ Infection (2)	None
Varadarajulu 2003 [44]	None	1 death from sepsis	None	▪ Clogging of tube (2)	▪ Pneumonia with sepsis (1)	▪ Clogging of tube (2)
Bueno JT 2003 [27]	None	6 deaths unrelated to PEG placement	None	▪ Site infection (2) ▪ Ileus (1) ▪ Diarrhea (1)	▪ Site infection (2) ▪ Persistent ileus (1) ▪ Diarrhea (1)	None

▶ **Table 2** (Continuation)

Author/ Year	Mechanisms for failure after initiating feeds	Major adverse event – All-cause mortality	Major adverse event requiring intervention – surgery or repeat endoscopy	Minor adverse events	Short term (< 30 days)	Long term (> 30 days)
Maple 2005 [45]	N/A	6 deaths (1 attributable to DPEJ)	▪ Bowel perforation (7) ▪ Major bleeding (3) ▪ Jejunal volvulus (3) ▪ Aspiration (2) ▪ enterocutaneous fistula (9) ▪ Severe pain requiring removal (5) ▪ Site infection needing drainage (2) ▪ Jejunal hematoma (1) ▪ Jejuno-colonic fistula (1)	▪ PEJ site infection (23) ▪ Prolonged PEJ tube site pain (14) ▪ Adverse reaction to sedation (5)	▪ Bowel perforation (7) ▪ Major bleeding (3) ▪ Jejunal Volvulus (3) ▪ Adverse reaction to sedation (5) ▪ Aspiration (2)	▪ Chronic enterocutaneous fistula (9) ▪ Severe pain requiring removal (5) ▪ PEJ site infection
Del Piano M 2008 [29]	None	None	None	▪ Abdominal wall infection (1)	▪ Abdominal wall infection (1)	None
Mackenzie 2008 [30]	N/A	1 death	▪ Necrotizing fasciitis (1) ▪ Jejunal volvulus (2) ▪ Jejunal obstruction (1) ▪ Sepsis (1)	▪ Severe pain (14) ▪ Peristomal infection (12)	▪ Necrotizing fasciitis (1) ▪ Jejunal obstruction (1) ▪ Jejunal Volvulus (2) ▪ Sepsis (1) ▪ Peristomal infection ▪ Pain	▪ Peristomal infection ▪ Pain
Panagiotakis 2008 [31]	None	3 death unrelated to DPEJ	▪ Tube degradation and occlusion (4)	▪ Peristomal infection (2) ▪ Fistula after DPEJ removal (1) ▪ Aspiration (3)	▪ Aspiration ▪ Peristomal infection	▪ Tube occlusion/ degradation (4) ▪ Fistula after DPEJ removal (1) ▪ Aspiration ▪ Peristomal infection
Moran 2009 [32]	None	14 deaths	▪ Bilous leakage from the site (1)	None	▪ Bilious leakage from DPEJ site	▪ Bilious leakage from DPEJ site
Aktas 2012 [33]	Unintentionally placed in the afferent loop (1)	None	None	▪ Recurrent aspiration with pneumonia (1) ▪ Gastropareisis with vomting (1)	▪ Gastropareisis (1)	▪ Apsiration with pneumonia (1)
Song 2012 [46]	None	None	None	▪ Peristomal cellulitis (1)	▪ Peristomal cellulitis (1)	N/A
Toussaint 2012 [34]	Intolerance to feeds (1)	3 deaths during f/u unrelated to the procedure	▪ Jejunal Volvulus (1) ▪ Jejunocolic fistula (1) ▪ Migration (2)	None	▪ Jejunal Volvulus (1)	▪ Jejunocolic fistula (1) ▪ Migration of tube (2)

▶ **Table 2** (Continuation)

Author/Year	Mechanisms for failure after initiating feeds	Major adverse event – All-cause mortality	Major adverse event requiring intervention – surgery or repeat endoscopy	Minor adverse events	Short term (<30 days)	Long term (>30 days)
Lim 2015 [47]	None	27 death from underlying disease	▪ Tube blockage with replacement (6) ▪ Gastric perforation (1) ▪ Jejunal perforation during tube replacement (1)	▪ Peristomal infection (3) ▪ Leakage around the stoma (4) ▪ Minor bleeding (2) ▪ Aspiration (1)	▪ Gastric Perforation (1) ▪ Peristomal infection (3) ▪ Peristomal leakage (4) ▪ Minor bleeding (2) ▪ Aspiration (1)	▪ Tube blockage with replacement (6) ▪ Jejunal perforation during tube replacement (1)
Velázquez-Aviña 2015 [35]	None	None	▪ Accidental removal with immediate replacement (1)	▪ Jejunostomy site infection (1)	None	▪ 5 planned removals ▪ One accidental removal with immediate replacement
Al-Bawardy 2016 [36]	N/A	None	▪ Gastric Interposition (1)	▪ Abdominal Hematoma (2)	▪ Limited GI bleeding from PEJ site ulceration/cellulitis (4) ▪ PEJ tube kink (1)	N/A
Bernardes 2017 [37]	None	None	▪ Jejunal perforation during the procedure (1)	None	None	▪ Accidental exteriorization of the PEJ bumper (2) at 10 and 13 months
Strong 2017 [24]	None	None	▪ Tube dislodgement (10) ▪ Bowel Obstruction (1) ▪ Volvulus (1) ▪ Repeat endoscopy with tube exchange (16)	▪ Aspiration event during induction of general anesthesia (1) ▪ Superficial wound infection at jejunostomy site treated with oral antibiotics (1)	▪ Leakage around the tube with skin maceration (1) ▪ Tube blockage without need for repeat endoscopy (1) ▪ Tube dislodgement with repeat endoscopy and replacement (1)	▪ Re-endoscopy (16) ▪ Tube exchange (17) ▪ Tube Leakage (10) ▪ Tube blockage (4) ▪ Tube dislodgment (10) ▪ Bowel Obstruction (1) ▪ Volvulus (1) ▪ Permanent Removal (4)
Kirstein 2018 [39]	N/A	N/A	▪ Pneumoperitoneum (1) ▪ PEG-J dislocation/dysfunction (26) ▪ PEG dysfunction (5)	▪ Local infection (2) ▪ Obstipation (2)	N/A	N/A

▶ **Table 2** (Continuation)

Author/ Year	Mechanisms for failure after initiating feeds	Major adverse event – All-cause mortality	Major adverse event requiring intervention – surgery or repeat endoscopy	Minor adverse events	Short term (< 30 days)	Long term (> 30 days)
Ridtitid 2018 [38]	N/A	N/A	▪ Jejunal tube clogging (47) ▪ Jejunal tube kinking (24) ▪ Jejunal tube dislogement (52) ▪ Buried Bumper (2)	▪ Cellulitis (21) ▪ Intolerance to feeds (10)	▪ Jejunal tube clogging (7) ▪ Jejunal tube kinking (10) ▪ J-tube dislodgement (6) ▪ Ballon malfunction (1) ▪ Buried bumper (2) ▪ Cellulitis (2)	▪ Jejunal tube clogging (40) ▪ Jejunal tube kinking (14) ▪ Dislodgement (46) ▪ Ballon malfunction (30) ▪ Cellulitis (19)
Simoes 2018 [40]	Intolerance to feeds - peritoneal carcinomatosis	202 death by the end of f/u	▪ Bleeding requiring endoscopy (5) ▪ Small bowel obstruction (1) ▪ Intra-abdominal abscess with CT guided drainage (2) ▪ Intussusception/ SBO (1) ▪ Respiratory failure (1)	▪ Bleeding (2) ▪ Abscess with partial SBO (1) ▪ Refeeding Syndrom (1) ▪ Peristomal infection (25) ▪ Leakage (30) ▪ Diarrhea (11) ▪ Tube dysfunction (3)	▪ Bleeding ▪ Small bowel obstruction ▪ Intra-abdominal abcess ▪ Anesthesia-related respiratory failure	N/A
Cococcia 2020 [25]	N/A	N/A	▪ Accidental removal (4) ▪ Jejunal extension dislocation (16) ▪ Obstruction/Kinking (10) ▪ Buried bumper syndrome (11) ▪ Tube malfunction (3)	▪ Hypergranulation tissue (4) ▪ Pyloric Ulcer (1)	▪ Jejunal extension dislocation (7) ▪ Accidental removal (2) ▪ Obstruction (2) ▪ Kinking (1)	▪ Obstruction (7) ▪ Tube malfunction (3) ▪ J-tube dislocation (9) ▪ Pyloric ulcer (1) ▪ Hypergranulation tissue (4) ▪ Buried bumper syndrome (11) ▪ Accidental removal (2)
Nishiwaki 2021 [48]	N/A	Pneumonia with respiratory failure (1)	▪ Upper GI bleeding (3) ▪ Colocutaneous fistula (2) ▪ Pneumoperitoneum (1) ▪ Tube dislodgement (8) ▪ Buried bumper syndrome (2)	▪ Fistula infection (5) ▪ Peristomal leakage (23) ▪ Pneumonia (28) ▪ Diarrhea (7) ▪ Vomiting (6) ▪ Granuloma (4) ▪ Ileus (2)	▪ Fistula infection (5) ▪ Gastrointestinal bleeding (2) ▪ Colocutaneous fistula (2) ▪ Pneumonia (1) ▪ Pneumoperitoneum (1)	▪ Pneumonia (27) ▪ Peristomal leakage (23) ▪ Tube dislodgement (8) ▪ Diarrhea (7) ▪ Vomiting (6) ▪ Granuloma (4) ▪ Buried bumper syndrome (2) ▪ Ileus (2)

BMI, body mass index; cal, calories; CVA, cerberocascular accident; DPEJ, direct percutaneous endoscopic jejunostomy; Fr, French; GI, gastrointestinal; IV, intravenous; J-tube,jJejunostomy tube; N/A, not applicable; PEG, percutaneous endoscopic gastrostomy; PEJ, percutaneous endoscopic jejunostomy; PEG-J, jejunal extension through PEG; SD, standard deviation.

▶ Table 3 Baseline patient characteristics.

Author/ Year	Procedure type	Total patients (n)	Age	Male/ female	Follow-up duration (days)	BMI (mean ± SD)	Indication for procedure	Native gut	Altered gut	Outcome	Feeding used and calories
Ponsky 1984 [20]	PEG-J	10	NR	N/A	N/A	N/A	Severely neurological impairment with aspiration and need for long-term enteral nutrition	Native gut (10)	None	▪ Technical success ▪ Procedure-related complications	▪ Tube feeds started the next day
Shike 1987 [21]	DPEJ	11	NR	N/A	N/A	N/A	Nutritional support in patients with GI malignancy	None	▪ Altered Gut (10) ▪ Gastric carcinoma s/p gastrectomy (5) ▪ Pancreatic cancer s/p Whipple (2) ▪ Non-operable pancreatic cancer with prior PEG (2) ▪ Esophagectomy and gastric pull up (1)	▪ Technical success ▪ Procedure-related complications ▪ Ability to provide adequate enteral nutrition	900–2400 calories/day
Kaplan 1989 [22]	PEG-J	23	67 ± 11	23/0	141	N/A	Recurrent aspiration pneumonia (23)	Native Gut (22) ▪ Alzheimer's (11) ▪ Stroke (6) ▪ Huntington's (1) ▪ Organic brain syndrome related to alcohol (1) ▪ Head/neck cancer (1)	Altered Gut (1) ▪ tracheo-esophageal fistula	▪ Placement of the PEJ tubes ▪ Acute and chronic complications ▪ Overall survival of the patients after PEJ placement	Tube feeds started the next day 75 to 100 mL/hr
Shike 1991 [41]	DPEJ	6	60 ± 5	2/4	180	N/A	▪ Duodenal/ gastric outlet obstruction (2) ▪ Aspiration (2) ▪ Gastric drainage (1) ▪ Gastric dysmotility (1)	Native Gut (6) ▪ Gastric cancer (2) ▪ Ovarian cancer (1) ▪ Pancreatic cancer (1) ▪ Brain tumor (1) ▪ Tongue cancer (1)	None	▪ Technical success ▪ Procedure-related complications	N/A

▶Table 3 (Continuation)

Author/ Year	Procedure type	Total patients (n)	Age	Male/ female	Follow-up duration (days)	BMI (mean ± SD)	Indication for procedure	Native gut	Altered gut	Outcome	Feeding used and calories
Mellert 1993 [42]	DPEJ	44	60 ± 20	N/A	30–510	N/A	▪ Malnutrition after gastric/ esophageal surgery ▪ Insufficient anastomosis or stenosis after surgery ▪ Perforation/fistula ▪ Trauma	Native gut (2) ▪ trauma	Altered Gut (39) ▪ Partial or total gastrectomy (19) ▪ Esophageal resection and esophagojejunostomy (13) ▪ Esophageal perforation (3) ▪ Fistula (2)	▪ Technical success ▪ Procedure related complications	N/A
Shike 1996 [43]	DPEJ	150	63 ± 12	93/57	113 ± 173	N/A	▪ Gastric outlet obstruction (56) ▪ Recurrent/potential aspiration (51) ▪ Anorexia (16) ▪ Proximal small bowel obstruction (16) ▪ Gastroesophageal anastomotic leak (6) ▪ Gastroparesis (5)	Native Gut (66)	Altered Gut (84) ▪ Total (6) Subtotal (30) gastrectomy ▪ Esophagectomy (17) ▪ Esophagogastrectomy (17) ▪ Whipple's procedure (6) ▪ Pancreatectomy (1)	▪ Technical success ▪ Procedure-related complications ▪ Long term outcomes with DPEJ	Tube feeds started as soon as awake Rate 50–75 mL/hour 30 to 40 kcal/kg/day
Rumalla 2000 [23]	DPEJ	36	52 ± 14	14/22	179 ± 109	N/A	▪ Gastroparesis (15) ▪ Aspiration (8) ▪ Gastric carcinoma/ obstruction (7) ▪ GI surgery with enteral nutrition (4) ▪ Chronic Pancreatitis (2)	Native Gut (28) ▪ Aspiration risk (8) ▪ Gastroparesis (15) ▪ Pancreatitis (2) ▪ Gastric outlet obstruction (3)	Altered Gut (8) ▪ Gastrojejunostomy (4) ▪ Esophageal resection/gastric pull up (3) ▪ Gastrectomy (1)	▪ Technical success of the procedure ▪ Procedure-related complications ▪ Need for reintervention for jejunal access	2835–9425 kJ/day Rate 60–125 mL/hour

▶ Table 3 (Continuation)

Author/ Year	Procedure type	Total patients (n)	Age	Male/ female	Follow-up duration (days)	BMI (mean ± SD)	Indication for procedure	Native gut	Altered gut	Outcome	Feeding used and calories
Barrera 2001 [26]	DPEJ	17	59 ± 17	11/6	60	N/A	▪ Aspiration pneumonia (9) ▪ Intolerance of gastric enteral feeding (4) ▪ Anastomotic leak after esophagectomy with gastric pull up (3) ▪ Duodenal obstruction (1)	Native gut (13) ▪ aspiration pneumonia ▪ Intolerance to gastric feeds ▪ duodenal obstruction	Altered Gut (4) ▪ anastomotic leak ▪ duodenal obstruction	▪ Technical success of the procedure ▪ Procedure-related complications ▪ Ability to provide adequate nutritional support	Tube feeds started at 24 hours Mean 1,988 Kcal/day (1440–2700)
Shetzline 2001 [28]	DPEJ	7	47 ± 16	4/3	146 ± 81	N/A	▪ Aspiration pneumonia (1) ▪ Neurological disease (1) ▪ Duodenal obstruction (2)	Native gut (4)	Altered gut (3)	▪ Successful placement	N/A
Varadarajulu 2003 [44]	DPEJ	26	46 ± 25	12/14	220 ± 122	N/A	▪ Malnutrition after gastric resection/surgery (10) ▪ Duodenal stricture (2) ▪ Failure to thrive (2) ▪ Pancreatic cancer with duodenal obstruction (1)	Native gut (10) ▪ Gastroparesis (5) ▪ Severe Pancreatitis (5)	Altered Gut (16) ▪ gastrojejunostomy (5) ▪ gastrectomy (2) ▪ pancreaticoduodenectomy (2) ▪ esophageal resection with gastric pull up (1) ▪ small bowel transplant (1) ▪ Pancreatic-renal transplant (1)	▪ Technical success of the procedure ▪ Procedure-related complication ▪ Ability to provide adequate nutritional support	Tube feeds started at 24 hours
Bueno JT 2003 [27]	DPEJ	25	65 ± 11	18/7	151 ± 104	N/A	▪ Anastomotic leak (21) ▪ Aspiration (4) ▪ Chylous leak (2) ▪ Prolonged ileus (2)	None	Altered Gut (25) ▪ Esophagectomy all	▪ Technical success of the procedure ▪ Procedure-related complications ▪ Enteral feeding ▪ Overall outcomes	Tube feeds started at 24 hours Mean 1667 kcal/day (1500–3180)

▶ Table 3 (Continuation)

Author/ Year	Procedure type	Total patients (n)	Age	Male/ female	Follow-up duration (days)	BMI (mean ± SD)	Indication for procedure	Native gut	Altered gut	Outcome	Feeding used and calories
Maple 2005 [45]	DPEJ	286	59 ± 17	145 / 141	251	N/A	▪ High risk for aspiration ▪ Status-post gastric resection ▪ Esophagogastrectomy ▪ Gastric outlet obstruction ▪ Obstructed or non-functioning gastrojejunostomy ▪ Gastric dysmotility	Native Gut (151) ▪ Esophageal/ gastric/pancreatic or colon cancer (81) ▪ Gastroparesis (61) ▪ High-risk aspiration (37) ▪ Persistent vomiting (16) ▪ Pancreatitis (9)	Altered Gut (58) ▪ Partial gastrectomy (24) ▪ Esophagectomy (20) ▪ Total gastrectomy (5) ▪ Esophagus-gastrectomy (3) ▪ Gastric Bypass (2) ▪ Intrathoracic stomach (4)	▪ Technical success ▪ Complication related to the placement of DPEJ and severity of complications	Tube feeds started at 24 hours
Del Piano M 2008 [29]	DPEJ	9	68 ± 8	NR	720	N/A	PEG not feasible/indicated ▪ Gastric herniation ▪ Organ interposition ▪ Gastric outlet obstruction ▪ Gastroparesis ▪ High risk of aspiration	Native gut (1)	Altered Gut (8) ▪ organ interposition (7) ▪ gastric herniation (1)	▪ Technical success and outcomes of DPEJ ▪ Procedure-related complications	Tube feeds started after 24 hours
Mackenzie 2008 [30]	DPEJ	75	41 ± 18	21 //54	210 ± 261	N/A	▪ Gastropareisis (23) ▪ Aspiration high risk (14) ▪ Pancreatitis (14) ▪ Nausea/vomiting (8) ▪ Postsurgical anatomy (7) ▪ Malignancy (5)	Native Gut (68) ▪ Gastroparesis (23) ▪ Aspiration high risk (14) ▪ Pancreatitis (14) ▪ Nausea/vomiting (8)	Altered Gut (7)	▪ Successful placement in overweight/obese patients ▪ Complications related to procedure and severity	N/A

▶ **Table 3** (Continuation)

Author/ Year	Procedure type	Total patients (n)	Age	Male/ female	Follow-up duration (days)	BMI (mean ± SD)	Indication for procedure	Native gut	Altered gut	Outcome	Feeding used and calories
Panagiotakis 2008 [31]	DPEJ	11	50 ± 22	7/4	627 ± 450	N/A	▪ Recurrent aspiration or aspiration pneumonia	Native gut (10) ▪ Neurological disease (9) ▪ Severe debility (1)	Altered gut (1) ▪ Esophageal surgery	▪ Weight before and after DPEJ placement ▪ Complications of DPEJ placement ▪ Aspiration events before and after the DPEJ placement	N/A
Moran 2009 [32]	DPEJ	40	69 ± 15	23/17	1080	N/A	Unable to maintain nutrition orally and if conventional endoscopic gastrostomy insertion was inappropriate	Native Gut (19) ▪ Esophageal/gastric/pancreatic malignancy ▪ Gastric dysmotility ▪ Cerebral palsy ▪ Pancreatitis	Altered Gut (21) ▪ gastric/esophageal malignancy postoperative recurrence ▪ Postoperative malnutrition ▪ Acute cerebrovascular disease with gastric resection	▪ Technical success ▪ Procedure-related complications	N/A
Aktas 2012 [33]	SBE-DPEJ	11	54 ± 17	7/4	N/A	N/A	▪ Recurrent aspiration (5) ▪ Gastric dysmotility (4) ▪ Duodenal cancer (2) ▪ Gastric Cancer (1)	Native gut (8)	Prior PEG or PEG-J in 4 patients	▪ Successful placement of DPEJ ▪ Rate of complications after DPEJ placement	N/A
Song 2012 [46]	DBE-DPEJ	10	59 ± 19	2/8	30	25 ± 6.25	▪ Gastroparesis (4) ▪ CVA with dysphagia (2) ▪ Aspiration pneumonia (3) ▪ Inadequate oral intake (1)	Native gut (6)	▪ Pancreaticoduodenectomy (1) ▪ Roux-en-Y gastric bypass(2) ▪ Roux-en-Y esophagojejunostomy (1)	▪ Successful placement of DBE assisted DPEJ ▪ Adverse events related to DBE assisted DPEJ	N/A

Table 3 (Continuation)

Author/Year	Procedure type	Total patients (n)	Age	Male/female	Follow-up duration (days)	BMI (mean ± SD)	Indication for procedure	Native gut	Altered gut	Outcome	Feeding used and calories
Toussaint 2012 [34]	DPEJ	12	54 ± 13	4/8	255 ± 114	17.6 ± 2.9	▪ Malnutrition associated with gastroparesis	Native gut (12)	None	▪ Technical success ▪ Complications related to placement ▪ Tolerance of enteral feeds ▪ Overall outcomes	Tube feeds started 24 hours after tube placement
Lim 2015 [47]	DPEJ	83	55 ± 2	51/32	2520	23.8 ± 0.5	▪ Dysphagia related to GI malignancy (17) ▪ Neuromuscular disease (13) ▪ Refractory gastroparesis (30) ▪ Dysphagia from prior surgery (5) ▪ Treatment of parkinsons with intrajejunal infusion (18)	Native gut (45) ▪ GI malignancy ▪ Neuromuscular disease ▪ Parkinson's disease ▪ Gastroparesis	Altered gut (30) ▪ prior PEG tube (29) ▪ prior GI surgery (5)	▪ Rates of technical success ▪ short term and long term complications ▪ long term clinical effects	N/A
Velázquez-Aviña 2015 [35]	SBE-DPEJ	25	54 ± 24	13/12	188 ± 95	20.9 ± 3.3	▪ Enteral feeding that could not be provided by gastrostomy (5) ▪ Status post-gastrectomy or gastric pull up (6) ▪ Complex fistula (6) ▪ Necrotizing Pancreatitis (7) ▪ Sarcoma with bowel obstruction (1)	Native gut ▪ Necrotizing pancreatitis ▪ Sarcoma with bowel obstruction	Altered gut ▪ Status post-gastrectomy or gastric pull up ▪ Complex fistula	▪ Placement of DPEJ ▪ Subsequent usage of DPEJ for enteral feeding ▪ Planned and unplanned removal	Tube feeds started at 12 hours

▶ **Table 3** (Continuation)

Author/Year	Procedure type	Total patients (n)	Age	Male/female	Follow-up duration (days)	BMI (mean ± SD)	Indication for procedure	Native gut	Altered gut	Outcome	Feeding used and calories
Al-Bawardy 2016 [36]	DBE-DPEJ	94	55 ± 20	39/55	30	23 ± 6.4	▪ Gastroparesis (29) ▪ Malnutrition and altered gut anatomy (17) ▪ Recurrent aspiration with PEG (14) ▪ Failed PEG (16) ▪ Esophageal cancer (7) ▪ Necrotizing Pancreatitis (6) ▪ Partial duodenal obstruction/perforation (5)	Native gut (58) ▪ Gastroparesis (29) ▪ Esophageal malignancy (7) ▪ Necrotizing Pancreatitis (6) ▪ Partial duodenal obstruction/perforation (5)	Altered gut (36) ▪ Roux-en-Y gastric bypass (17) ▪ Billroth ii anatomy (5) ▪ Whipple's anatomy (3) ▪ Ivor Lewis Anatomy (5) ▪ Other (6) – gastric sleeve, duodenal resection	▪ Placement of DPEJ ▪ Cause of placement failure ▪ Procedure-related adverse events ▪ Adverse events over 1 month period	N/A
Bernardes 2017 [37]	SBE-DPEJ	23	68 ± 16	17/6	345 ± 294	N/A	▪ Contraindication for gastric feeding or failure of PEG tube insertion ▪ Severe gastric or esophageal cancer ▪ Neurological disease ▪ Necrotizing Pancreatitis ▪ Heck and neck cancer	▪ Unsuccessful PEG tube (3) ▪ Gastric outlet obstruction (7) ▪ Severe PUD (1) ▪ Severe Gastroparesis (1) ▪ Necrotizing Pancreatitis (1)	▪ Partial Gastrectomy (10)	▪ Technical success ▪ Effective use of PEJ for feeding in those with technical success ▪ Procedure-related complications ▪ Adverse events until death or removal of the tube	Enteral diet started the same day

▶ Table 3 (Continuation)

Author/ Year	Procedure type	Total patients (n)	Age	Male/ female	Follow-up duration (days)	BMI (mean ± SD)	Indication for procedure	Native gut	Altered gut	Outcome	Feeding used and calories
Strong 2017 [24]	DPEJ	59	50 ± 17	24/35	89	24.6 ± 8.2	▪ Severe dehydration/malnutrition (29) ▪ Gastroparesis (9) ▪ Cancer of the upper esophageal tract (7) ▪ Complication of bariatric surgery (4) ▪ Malfunction of prior enteral access (4) ▪ Other (6)	Native gut (2)	Altered Gut (57) ▪ Prior bariatric surgery (19 ▪ Non-bariatric surgery (51)	▪ Placement of DPEJ ▪ Outcomes at 30 days and long term ▪ Complications of procedure short and long term	Tube feeds started at 24 hours
Kirstein 2018 [39]	DPEJ	39	65 ± 5	22/17	421	21.9 ± 3.4	ALS with the need for enteral nutrition	None	Altered Gut (39) ▪ Prior PEG tube placement	▪ Overall survival ▪ Intervention/ feeding-related complications ▪ Complication free survival	N/A
Ridtitid 2018 [38]	PEG-J	102	51 ± 18	31/71	495 ± 173		▪ Intolerance to eating ▪ Severe acute or chronic pancreatitis ▪ Recurrent aspiration.	Native Gut (86) ▪ chronic pancreatitis (53) ▪ Cancer with malnutrition (12) ▪ chronic vomiting (21) ▪ recurrent acute/ necrotizing pancreatitis (10) ▪ impaired swallowing (6)	Altered Gut (16) ▪ Roux-en-Y gastrojejunostomy (1) ▪ Whipple's (14) ▪ Duodenostomy (1)	▪ Short and long term complications of related to PEG-J placement ▪ Clinical impact on jejunal feeding on weight and hospitalization	Tube feeds initiated 12–24 hours 1.5 cal/mL daily

▶ **Table 3** (Continuation)

Author/ Year	Procedure type	Total patients (n)	Age	Male/ female	Follow-up duration (days)	BMI (mean ± SD)	Indication for procedure	Native gut	Altered gut	Outcome	Feeding used and calories
Simoes 2018 [40]	DPEJ	452	61 ± 21	316 / 136	634 ± 664	23.1 ± 5.5	▪ Anastomotic leak or proximal stricture ▪ Aspiration prevention ▪ Weight loss ▪ Gastroparesis ▪ Malignant gastric outlet obstruction ▪ Extrinsic GI tract compression	Native Gut (220) ▪ Malignant Gi tract obstruction	Altered Gut (260) ▪ prior esophagectomy with anastomosis ▪ Partial gastrectomy with anastomosis/roux-en-y or gastrojejunal loop anastomosis ▪ Total gastrectomy with esophagojejunal anastomosis ▪ Whipple's procedure	▪ Procedural success ▪ Immediate and delayed adverse events within and after 7 days	Tube feeds initial within 24 hours 1775 calories (384–3744 daily)
Cococcia 2020 [25]	PEG-J	73	70 ± 10	29 / 44	683 ± 262	N/A	▪ Parkinson's disease requiring levodopa-carbidopa intestinal gel ▪ Conditions with dysphagia or persistent vomiting – Huntington's chorea, cerebral vasculopathy, subarachnoid hemorrhage, Angelman syndrome	Native Gut (73) ▪ Parkinson's disease with LCIG ▪ Conditions with dysphagia or persistent vomiting	None	▪ Adverse events that required reintervention ▪ Short term and long term adverse events	N/A

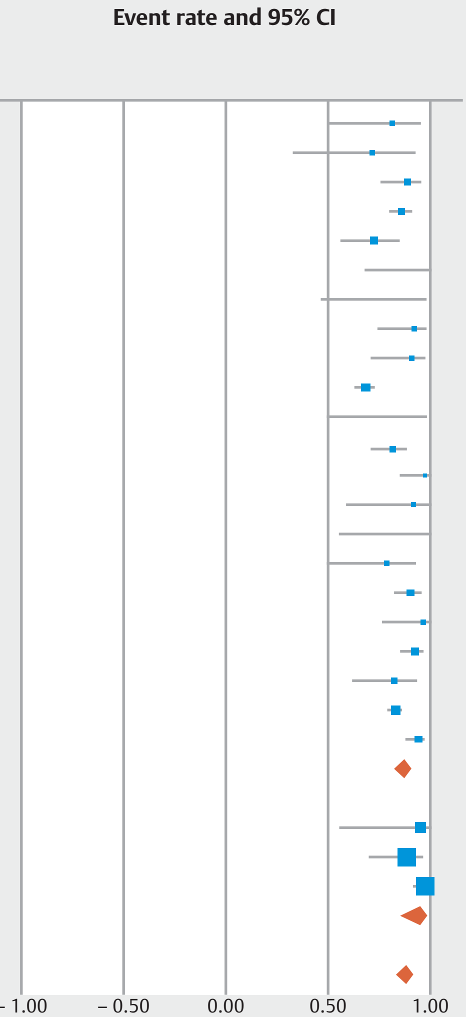
▶ Table 3 (Continuation)

Author/Year	Procedure type	Total patients (n)	Age	Male/female	Follow-up duration (days)	BMI (mean ± SD)	Indication for procedure	Native gut	Altered gut	Outcome	Feeding used and calories
Nishiwaki 2021 [48]	DPEJ	115	81 ± 3	59/56	696 ± 343	N/A	▪ Cerebrovascular disease requiring enteral nutrition ▪ Malignant GI tumors ▪ Neuromuscular disease ▪ Gastric outlet obstruction ▪ Prior foregut surgery ▪ No transillumination at PEG	Native gut (61)	Altered Gut (54) ▪ Billroth I and II reconstruction ▪ Total gastrectomy ▪ Esophagectomy	▪ Comparison of survival outcomes in PEG and DPEJ ▪ Placement of the tube ▪ Comparison of the adverse events between PEG and DPEJ	Tube feeds initiated the day after the procedure

BMI, body mass index; cal, calories; CVA, cerberocascular accident; DPEJ, direct percutaneous endoscopic jejunostomy; Fr, French; GI, gastrointestinal; IV, intravenous; J-tube,jJejunostomy tube; N/A, not applicable; PEG, percutaneous endoscopic gastrostomy; PEJ, percutaneous endoscopic jejunostomy; PEG-J, jejunal extension through PEG; SD, standard deviation.

Technical success

Group by Endoscopic Approach	Study name	Event rate	Lower limit	Upper limit	Z-Value	*p*-Value
DPEJ	Shike 1987	0.818	0.493	0.954	1.924	0.054
DPEJ	Shike 1991	0.714	0.327	0.928	1.095	0.273
DPEJ	Mellert 1994	0.886	0.755	0.952	4.324	0.000
DPEJ	Shike 1996	0.860	0.795	0.907	7.714	0.000
DPEJ	Rumalla 2000	0.722	0.556	0.844	2.568	0.010
DPEJ	Barrera 2001	0.972	0.678	0.998	2.479	0.013
DPEJ	Shetzline 2001	0.875	0.463	0.983	1.820	0.069
DPEJ	Varadarajulu 2003	0.923	0.739	0.981	3.376	0.001
DPEJ	Bueno JT 2003	0.909	0.700	0.977	3.105	0.002
DPEJ	Maple 2005	0.681	0.627	0.731	6.186	0.000
DPEJ	Del Piano M 2008	0.889	0.500	0.985	1.961	0.050
DPEJ	Mackenzie 2008	0.813	0.712	0.884	5.119	0.000
DPEJ	Moran 2009	0.976	0.846	0.997	3.644	0.000
DPEJ	Aktas 2012	0.917	0.587	0.988	2.296	0.022
DPEJ	Song 2012	0.955	0.552	0.997	2.103	0.035
DPEJ	Toussaint 2012	0.786	0.506	0.929	1.995	0.046
DPEJ	Lim 2015	0.904	0.819	0.951	6.017	0.000
DPEJ	Velázquez-Aviña 2015	0.960	0.765	0.994	3.114	0.002
DPEJ	Al-Bawardy 2016	0.926	0.852	0.964	6.414	0.000
DPEJ	Bernardes 2017	0.826	0.618	0.933	2.832	0.005
DPEJ	Simoes 2018	0.829	0.793	0.860	13.026	0.000
DPEJ	Nishiwaki 2021	0.939	0.878	0.971	7.016	0.000
DPEJ		0.866	0.821	0.901	10.586	0.000
PEG-J	Ponsky 1984	0.955	0.552	0.997	2.103	0.035
PEG-J	Kaplan 1989	0.885	0.697	0.962	3.318	0.001
PEG-J	Ridtitid 2018	0.971	0.913	0.990	5.966	0.000
PEG-J		0.944	0.855	0.979	5.281	0.000
Overall		**0.876**	**0.836**	**0.908**	**11.709**	**0.000**



▶ **Fig. 1** Forest plot of pooled DPEJ and PEG-J technical success.

major adverse events rate of 1.3 % (CI, 0.3–5.2, I^2 < 0.001 %). There was a statistical significance, P = 0.04 (▶ **Fig. 3**). The true effect size in 95 % of all comparable populations falls in the interval 0.01–0.19 (DPEJ) and a common effect size within the PEG-J group.

Minor adverse events: DPEJ – 25 studies, 1473 patients had a pooled minor adverse events rate of 15.4 % (CI, 10.1–22.9, I^2 85.2 %), while PEG-J – four studies, 202 patients had a pooled minor adverse events rate of 25.0 % (CI, 14.3–40.0, I^2 67.6 %). The difference between both was not statistically significant, P = 0.16 (▶ **Fig. 3**). The true effect size in 95 % of all comparable populations falls in the interval 0.02–0.60 (DPEJ) and 0.02–0.84 (PEG-J).

Ease of endoscopic placement: 8 studies (DPEJ 7, PEG-J 1), 646 patients. First attempt successful placement was 87.6 % (95 % CI, 77.5 %–93.6 %, I^2 57.8 %) and second attempt successful placement at 90.2 % (95 % CI, 75.0 %–96.7 %, I^2 < 0.001 %).

Subgroup analysis

Technical success: DPEJ by device-assisted (single or double-balloon) enteroscopy had a pooled TS of 91.1 % (CI, 85.3–94.7, I^2 < 0.001), while non-device-assisted enteroscopy had a pool TS of 86.9 % (CI, 82.1–90.6, I^2 76.2 %). The difference between both was not statistically significant, P = 0.2.

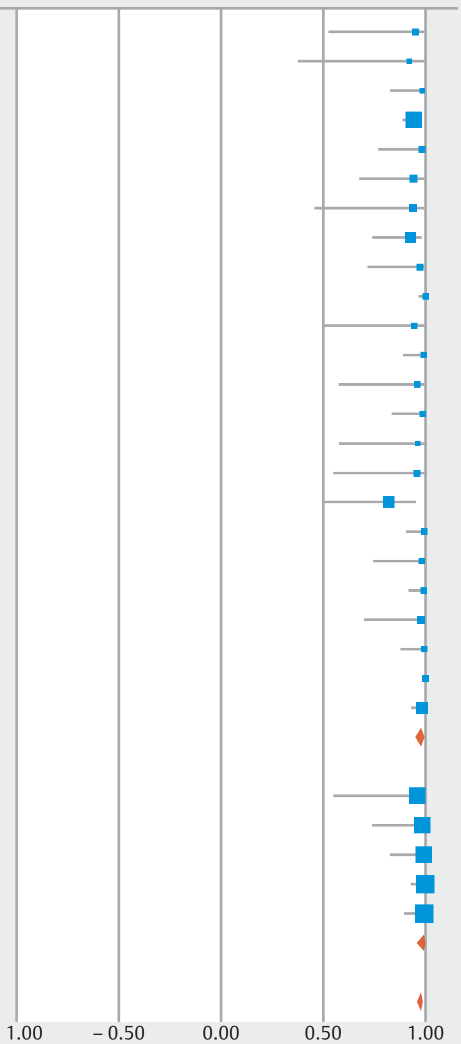
Malfunction rate: DPEJ by device-assisted enteroscopy had a malfunction rate of 4.60 % (CI, 1.40–14.4, I^2 38.9 %), while non-device-assisted enteroscopy had a malfunction rate of 14.4 % (CI, 9.3–21.7, I^2 85.3 %). The difference between both was not statistically significant, P = 0.07.

Major adverse event rate: DPEJ by device-assisted enteroscopy had a major adverse event rate of 3.5 % (CI, 1.3–9.1, I^2 < 0.001), while non-device-assisted enteroscopy had a major adverse event rate of 4.5 % (CI, 2.9–7.1, I^2 53.4 %). The difference between both was not statistically significant, P = 0.7.

Clinical success

Group by Endoscopic Approach	Study name	Statistics for each study: Event rate	Lower limit	Upper limit	Z-Value	*p*-Value
DPEJ	Shike 1987	0.950	0.525	0.997	2.029	0.042
DPEJ	Shike 1991	0.917	0.378	0.995	1.623	0.105
DPEJ	Mellert 1994	0.988	0.829	0.999	3.070	0.002
DPEJ	Shike 1996	0.946	0.891	0.974	7.354	0.000
DPEJ	Rumalla 2000	0.981	0.764	0.999	2.781	0.005
DPEJ	Barrera 2001	0.941	0.680	0.992	2.690	0.007
DPEJ	Shetzline 2001	0.938	0.461	0.996	1.854	0.064
DPEJ	Varadarajulu 2003	0.923	0.739	0.981	3.376	0.001
DPEJ	Bueno JT 2003	0.976	0.713	0.999	2.594	0.009
DPEJ	Maple 2005	0.998	0.963	1.000	4.264	0.000
DPEJ	Del Piano M 2008	0.944	0.495	0.997	1.947	0.052
DPEJ	Mackenzie 2008	0.992	0.890	1.000	3.434	0.001
DPEJ	Panagiotakis 2008	0.958	0.575	0.997	2.170	0.030
DPEJ	Moran 2009	0.988	0.833	0.999	3.088	0.002
DPEJ	Aktas 2012	0.958	0.575	0.997	2.170	0.030
DPEJ	Song 2012	0.955	0.552	0.997	2.103	0.035
DPEJ	Toussaint 2012	0.818	0.493	0.954	1.924	0.054
DPEJ	Lim 2015	0.993	0.903	1.000	3.536	0.000
DPEJ	Velázquez-Aviña 2015	0.980	0.749	0.999	2.724	0.006
DPEJ	Al-Bawardy 2016	0.994	0.916	1.000	3.642	0.000
DPEJ	Bernardes 2017	0.975	0.702	0.998	2.558	0.011
DPEJ	Strong 2017	0.992	0.880	0.999	3.365	0.001
DPEJ	Simoes 2018	0.999	0.980	1.000	4.721	0.000
DPEJ	Nishiwaki 2021	0.981	0.929	0.995	5.563	0.000
DPEJ		0.969	0.950	0.980	13.998	0.000
PEG-J	Ponsky 1984	0.955	0.552	0.997	2.103	0.035
PEG-J	Kaplan 1989	0.979	0.741	0.999	1.694	0.007
PEG-J	Kirstein 2018	0.988	0.829	0.999	3.070	0.002
PEG-J	Ridtitid 2018	0.995	0.925	1.000	3.734	0.000
PEG-J	Cococcia 2020	0.993	0.897	1.000	3.487	0.000
PEG-J		0.987	0.955	0.996	6.757	0.000
Overall		**0.972**	**0.957**	**0.982**	**15.490**	**0.000**

Event rate and 95% CI



▶ **Fig. 2** Forest plot of pooled DPEJ and PEG-J clinical success.

Minor adverse events rate: DPEJ by device-assisted enteroscopy had a minor adverse event rate of 5.5 % (CI, 1.7–16.3, I^2 37.6 %), while non-device-assisted enteroscopy had a minor adverse event rate of 19.3 % (CI, 13.4–27.0, I^2 = 85.5 %). There was a statistical significance, P = 0.03.

Altered anatomy – DPEJ TS was 87.8 % (CI, 84.9–90.2, I^2 < 0.001) and PEG-J was 81.6 % (CI, 58.1–93.4, I^2 < 0.001). The difference between both was not statistically significant, P = 0.4.

Native anatomy – DPEJ TS was 85.6 % (CI, 80.1–89.8, I^2 36.4%) and PEG-J was 97.4 % (CI, 90.0–99.3, I^2 < 0.001). There was a statistical significance of P = 0.01.

Validation of Meta-analysis Results

Sensitivity analysis

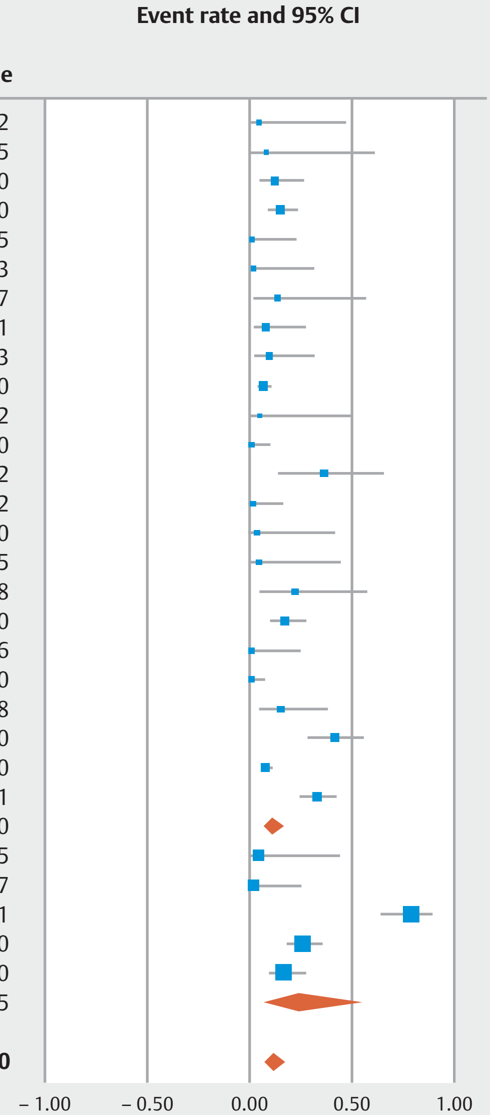
We completed a one-study removal sensitivity analysis to assess if one study had a dominant effect on the meta-analysis. Statistical significance and direction of findings for all outcomes remained unchanged.

Heterogeneity

The I^2 was moderately consistent > 75 % across outcomes suggesting considerable heterogeneity of our sample.

Malfunction

Group by Endoscopic Approach	Study name	Statistics for each study: Event rate	Lower limit	Upper limit	Z-Value	*P*-Value
DPEJ	Shike 1987	0.050	0.003	0.475	−2.029	0.042
DPEJ	Shike 1991	0.083	0.005	0.622	−1.623	0.105
DPEJ	Mellert 1994	0.128	0.054	0.273	−4.002	0.000
DPEJ	Shike 1996	0.155	0.095	0.241	−6.049	0.000
DPEJ	Rumalla 2000	0.019	0.001	0.236	−2.781	0.005
DPEJ	Barrera 2001	0.028	0.002	0.322	−2.479	0.013
DPEJ	Shetzline 2001	0.143	0.020	0.581	−1.659	0.097
DPEJ	Varadarajulu 2003	0.083	0.021	0.279	−3.247	0.001
DPEJ	Bueno JT 2003	0.100	0.025	0.324	−2.948	0.003
DPEJ	Maple 2005	0.067	0.040	0.110	−9.520	0.000
DPEJ	Del Piano M 2008	0.056	0.003	0.505	−1.947	0.052
DPEJ	Mackenzie 2008	0.015	0.002	0.101	−4.127	0.000
DPEJ	Panagiotakis 2008	0.364	0.143	0.661	−0.893	0.372
DPEJ	Moran 2009	0.012	0.001	0.167	−3.088	0.002
DPEJ	Aktas 2012	0.042	0.003	0.425	−2.170	0.030
DPEJ	Song 2012	0.045	0.003	0.448	−2.103	0.035
DPEJ	Toussaint 2012	0.222	0.056	0.579	−1.562	0.118
DPEJ	Lim 2015	0.173	0.103	0.276	−5.121	0.000
DPEJ	Velázquez-Aviña 2015	0.020	0.001	0.251	−2.724	0.006
DPEJ	Al-Bawardy 2016	0.011	0.002	0.077	−4.429	0.000
DPEJ	Bernardes 2017	0.158	0.052	0.392	−2.661	0.008
DPEJ	Strong 2017	0.417	0.287	0.559	−1.149	0.250
DPEJ	Simoes 2018	0.083	0.060	0.114	−13.222	0.000
DPEJ	Nishiwaki 2021	0.330	0.247	0.425	−3.425	0.001
DPEJ		0.108	0.070	0.163	−8.743	0.000
PEG-J	Ponsky 1984	0.045	0.003	0.448	−2.103	0.035
PEG-J	Kaplan 1989	0.021	0.001	0.259	−2.694	0.007
PEG-J	Kirstein 2018	0.795	0.640	0.894	3.416	0.001
PEG-J	Ridtitid 2018	0.263	0.185	0.358	−4.520	0.000
PEG-J	Cococcia 2020	0.171	0.100	0.278	−4.968	0.000
PEG-J		0.236	0.075	0.541	−1.721	0.085
Overall		**0.118**	**0.079**	**0.173**	**−8.817**	**0.000**



a

▶ **Fig. 3** Forest plot of pooled DPEJ and PEG-J malfunction rates, major and minor adverse events.**a** Malfunction rate.

Publication bias

There was asymmetry on the funnel plot in which small negative studies were missing, suggesting publication bias. Egger's test 1.93, 95 % CI 0.82–3.03, $P < 0.001$.

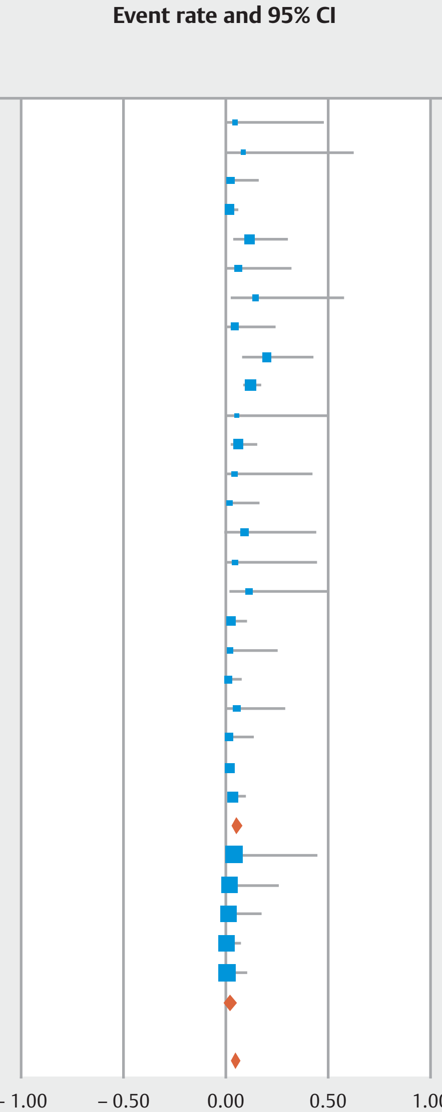
Discussion

To the best of our knowledge, this is the first systematic review and meta-analysis assessing the technical success, complications, and outcomes of direct percutaneous endoscopic jejunostomy (DPEJ) and percutaneous endoscopic gastrostomy with jejunal extension (PEG-J), using all existing studies since its initial description by Ponsky and Shike [20, 21]. Amongst 29 studies (n = 874), we found that DPEJ and PEG-J facilitated successful clinical feeding rates with high fidelity and consistent placement rates. DPEJ had fewer malfunction and failure rates, while PEG-J had higher placement rates. Subgroup analysis revealed that DPEJ performance could be enhanced using device-assisted (balloon) enteroscopy, resulting in higher placement rates in native or altered anatomy, lower malfunction and failure rates, and lower overall adverse events (major and minor). However, the differences were statistically insignificant between both groups. Overall, both DPEJ and PEG-J were found to have high success rates on first or second attempt placement.

The growing demand for conditions that require post-pyloric nutrition has expanded to include refractory gastroparesis, par-

Major adverse events

Group by Endoscopic Approach	Study name	Statistics for each study: Event rate	Lower limit	Upper limit	Z-Value	*P*-Value
DPEJ	Shike 1987	0.050	0.003	0.475	−2.029	0.042
DPEJ	Shike 1991	0.083	0.005	0.622	−1.623	0.105
DPEJ	Mellert 1994	0.026	0.004	0.161	−3.591	0.000
DPEJ	Shike 1996	0.020	0.006	0.060	−6.673	0.000
DPEJ	Rumalla 2000	0.115	0.038	0.303	−3.318	0.001
DPEJ	Barrera 2001	0.059	0.008	0.320	−2.390	0.007
DPEJ	Shetzline 2001	0.143	0.020	0.581	−1.659	0.097
DPEJ	Varadarajulu 2003	0.042	0.006	0.244	−3.069	0.002
DPEJ	Bueno JT 2003	0.200	0.077	0.428	−2.480	0.013
DPEJ	Maple 2005	0.120	0.082	0.171	−9.364	0.000
DPEJ	Del Piano M 2008	0.056	0.003	0.505	−1.947	0.052
DPEJ	Mackenzie 2008	0.062	0.023	0.153	−5.279	0.000
DPEJ	Panagiotakis 2008	0.042	0.003	0.425	−2.170	0.030
DPEJ	Moran 2009	0.012	0.001	0.167	−3.088	0.002
DPEJ	Aktas 2012	0.091	0.013	0.439	−2.195	0.028
DPEJ	Song 2012	0.045	0.003	0.448	−2.103	0.035
DPEJ	Toussaint 2012	0.111	0.015	0.500	−1.961	0.050
DPEJ	Lim 2015	0.027	0.007	0.100	−5.019	0.000
DPEJ	Velázquez-Aviña 2015	0.020	0.001	0.251	−2.724	0.006
DPEJ	Al-Bawardy 2016	0.011	0.002	0.077	−4.429	0.000
DPEJ	Bernardes 2017	0.053	0.007	0.294	−2.813	0.005
DPEJ	Strong 2017	0.021	0.003	0.134	−3.810	0.000
DPEJ	Simoes 2018	0.018	0.008	0.036	−10.549	0.000
DPEJ	Nishiwaki 2021	0.038	0.014	0.096	−6.354	0.000
DPEJ		0.050	0.033	0.076	−13.109	0.000
PEG-J	Ponsky 1984	0.045	0.003	0.448	−2.103	0.035
PEG-J	Kaplan 1989	0.021	0.001	0.259	−2.694	0.007
PEG-J	Kirstein 2018	0.013	0.001	0.171	−3.070	0.002
PEG-J	Ridtitid 2018	0.002	0.000	0.075	−3.734	0.000
PEG-J	Cococcia 2020	0.007	0.000	0.103	−3.487	0.000
PEG-J		0.013	0.004	0.045	−6.757	0.000
Overall		**0.043**	**0.029**	**0.064**	**−14.608**	**0.000**



b

▶ **Fig. 3** Forest plot of pooled DPEJ and PEG-J malfunction rates, major and minor adverse events. **b** Major adverse event rate,

tial or complete gastric outlet obstruction, acute or chronic pancreatitis, and partial gastrectomy. It has also recently found applicability in short bowel syndrome, dysmotility, and malignant chronic bowel obstruction [49, 50]. Gastroenterology practices have seen referrals for DPEJ increase due to their reliability compared to gastric feeding, making jejunal feeding more relevant than before [32]. Data suggests that enteral feeding started < 24 hours after elective gastrointestinal surgery reduces infection rates, length of stay, and mortality [51].

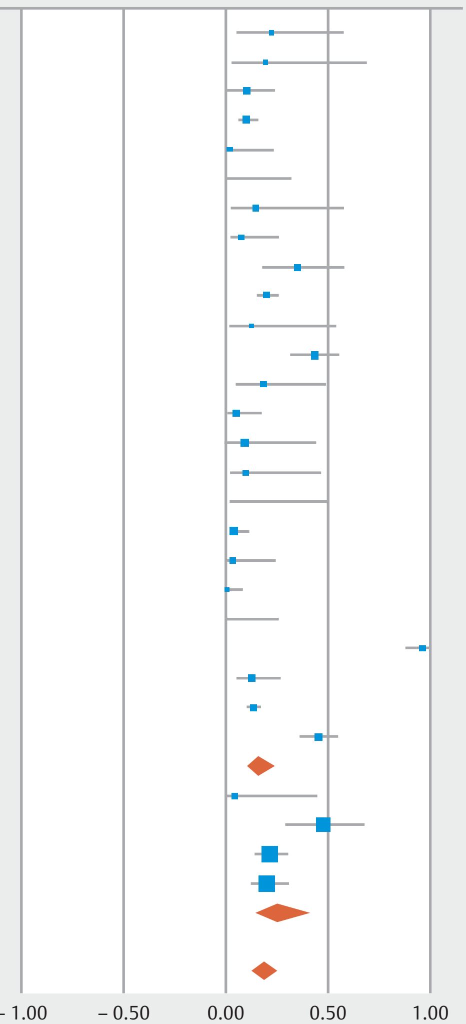
ASGE and ESGE recommend DPEJ and PEG-J as an accepted alternative to nasogastric or surgical jejunal feeding; however, patient selection is vague and often depends on anatomy, procedural know-how, and risk stratification to identify factors that may contribute to early failure [7, 11]. Head-to-head, DPEJ has fewer long-term complications and longer tube patency, but PEG-J has higher success rates but more significant malfunction [53]. These observations and society recommendations are supported by a low quality of evidence, serving as the basis for our study.

Societal guidelines have stressed the importance of careful attention, dexterity, and stabilization for successful placement. In patients with native anatomy, DPEJ is reserved for when the PEG-J fails, but instances of first-line are unknown and remain under the purview of hospital protocols [7, 11]. Additionally, a substantial number of patients with surgically altered anatomy require enteral access and endoscopic expertise, impacting

Minor adverse events

Group by Endoscopic Approach	Study name	Event rate	Lower limit	Upper limit	Z-Value	*P*-Value
		Statistics for each study				
DPEJ	Shike 1987	0.222	0.056	0.579	–1.562	0.118
DPEJ	Shike 1991	0.200	0.027	0.691	–1.240	0.215
DPEJ	Mellert 1994	0.103	0.039	0.243	–4.110	0.000
DPEJ	Shike 1996	0.100	0.061	0.159	–4.110	0.000
DPEJ	Rumalla 2000	0.019	0.001	0.236	–2.781	0.005
DPEJ	Barrera 2001	0.028	0.002	0.322	–2.479	0.013
DPEJ	Shetzline 2001	0.143	0.020	0.581	–1.659	0.097
DPEJ	Varadarajulu 2003	0.077	0.019	0.261	–3.376	0.001
DPEJ	Bueno JT 2003	0.350	0.177	0.574	–1.320	0.187
DPEJ	Maple 2005	0.201	0.152	0.261	–7.996	0.000
DPEJ	Del Piano M 2008	0.125	0.017	0.537	–1.820	0.069
DPEJ	Mackenzie 2008	0.431	0.317	0.553	–1.113	0.266
DPEJ	Panagiotakis 2008	0.182	0.046	0.507	–1.924	0.054
DPEJ	Moran 2009	0.050	0.013	0.179	–4.059	0.000
DPEJ	Aktas 2012	0.182	0.046	0.507	–1.924	0.054
DPEJ	Song 2012	0.100	0.014	0.467	–2.084	0.037
DPEJ	Toussaint 2012	0.111	0.015	0.500	–1.961	0.050
DPEJ	Lim 2015	0.040	0.013	0.117	–5.393	0.000
DPEJ	Velázquez-Aviña 2015	0.042	0.006	0.244	–3.069	0.002
DPEJ	Al-Bawardy 2016	0.006	0.000	0.084	–3.642	0.000
DPEJ	Bernardes 2017	0.021	0.001	0.259	–2.694	0.007
DPEJ	Strong 2017	0.966	0.874	0.992	4.656	0.000
DPEJ	Kirstein 2018	0.128	0.054	0.273	–4.002	0.000
DPEJ	Simoes 2018	0.133	0.103	0.170	–12.697	0.000
DPEJ	Nishiwaki 2021	0.453	0.361	0.548	–0.970	0.332
DPEJ		0.154	0.101	0.229	–6.849	0.000
PEG-J	Ponsky 1984	0.045	0.003	0.448	–2.103	0.035
PEG-J	Kaplan 1989	0.478	0.288	0.675	–0.208	0.835
PEG-J	Ridtitid 2018	0.212	0.143	0.304	–5.337	0.000
PEG-J	Cococcia 2020	0.200	0.122	0.310	–4.639	0.000
PEG-J		0.250	0.143	0.400	–3.104	0.002
Overall		**0.182**	**0.130**	**0.249**	**–7.389**	**0.000**

Event rate and 95% CI



c

▶ **Fig. 3** Forest plot of pooled DPEJ and PEG-J malfunction rates, major and minor adverse events. **c** Minor adverse event rate.

technical success. In our analysis, 621 patients (DPEJ 503, PEG-J 118) with altered anatomy had successful jejunal tube placement. DPEJ had higher placement rates PEG-J in these settings supporting similar success in smaller studies; however, the difference was not statistically significant. Most of the patients had a history of Billroth II or Roux-en-Y reconstruction, which involves dislodging the proximal jejunum from the retroperitoneal space and closer to the anterior abdominal wall. In cases of failure, most commonly in morbidly obese patients, balloon-enteroscopy can be an alternative. Our study reported higher success rates and fewer adverse outcomes, including tube malfunction in device-assisted (balloon use) than non-device-assisted enteroscopy during DPEJ; however, these were not statistically significant. Although there was a statistically significant difference in minor adverse events, suggesting that there is a significant learning curve and potential for improvement in device-assisted enteroscopy for DPEJ placement. Six DPEJ studies reported using fluoroscopy [28, 32, 35, 36, 46, 48].

Our analysis showed similar CS rates in patients with successful PEG-J and DPEJ placement without difference between the two, suggesting acceptable patency rates; however, CS was loosely defined amongst studies. Initiation of tube feeds was often within 24 hours, with Varadarajulu *et al.* reporting a mean time of 39 hours to achieve the dietary goal; however, meaningful clinical data such as patient tolerance, feeding rates, gastric residuals, or sequential data lack amongst known studies. Combined CS was 97.2 % (DPEJ 97.1 %, PEG-J 98.3 %), suggesting that these devices can tolerate and deliver the required caloric needs, but sophisticated mechanisms to support prolonged feeding are still required. The average time to malfunction or replacement was 162 ± 135 days. Although this finding was reported in a few studies [22, 24, 25, 27, 28, 37, 38, 40, 45, 47], the wide confidence interval highlights the high variability in the duration of patency and function of endoscopically placed jejunal tubes. Weight gain was also reported in a few studies [21, 31, 38, 47], with a mean weight gain of 4.6 ± 4.4 Kg, confirming their clinical utility. These findings near mirror PEG tube success rates suggesting that they are primed for widespread adaptability.

In terms of assessing tube malfunction, complications, or adverse events, studies reported safety outcomes heterogeneously, especially regarding the definition of peri-procedural complications. Tube malfunction can have various dispositions, including endoscopic, radiologic, or surgical revisit or bedside adjustments; however, these aspects were not delineated in our studies, so we grouped all cases into a separate group – malfunction. We used a combination of ASGE and ESGE based definitions to cast our net wide and capture as many safety-related events into malfunction, major and minor adverse events. PEG tubes have an overall complication rate of 16.7 %, with higher rates in frail patients [11]. In our study, the DPEJ malfunction rate was 11.9 %, while PEG-J was 17.4 %. The use of balloon enteroscopy further brought down malfunction rates; however, these findings were insignificant. PEG-J relies on safe and effective PEG tube placement, and higher malfunction rates could be due to sub-optimal PEG placement but often due to the J-arm size [45].

Major adverse events that required endoscopic, radiologic, or surgical revisit were seen in 5 % of DPEJ placements; the use of device-assisted enteroscopy showed no difference. Minor adverse events were reported with a high heterogeneity due to variability in the definition, with fewer events reported amongst DPEJ placements. Peri-procedural infections were <1% with 61 % of studies using peri-procedural antibiotics. Major adverse events outside tube dysfunction included major bleeding including hematoma (16), fistula (15), perforation (10), volvulus (8), severe infection such as peritonitis or abscess formation (7), and obstruction (6). Minor adverse events included outside tube leakage was minor bleeding (78), pain (27), aspiration (17), minor bleeding (11), ileus (4), and ulcers (2). We were able to obtain short and long-term outcomes; however, the data was unanalyzable. Most common < 30-day complications were leakage, infections, aspiration, volvulus, obstruction, bleeding, perforation, fistula. Long-term (> 30 days) complications included tube dysfunction/malfunction, fistulas, buried bumper syndrome, ileus, and pneumonia.

Bleeding can occur during trocar insertion from inadvertent damage to the abdominal blood vessels, most can be managed with external pressure and intraperitoneal bleeding is rare. The majority of the patients included had high comorbidity indexes, and anticoagulant use cannot be ruled out, contributing to bleeding. These findings are consistent with the incidence rates from the known literature (4.8 %–26.2 %) [7, 54]. Most studies used the modified Gauderer and Ponsky or Shike technique, and no head-to-head studies exist. Fluoroscopy was used in a few studies [28, 32, 35, 36, 38, 46, 48], primarily in repositioning or troubleshooting tube malfunction. Commonly used PEG tube sizes were 20 (13); however, a wide range can be seen in our study from 10–28 Fr, with J-arms from 8–12 Fr. In our study, the mean procedure time was 45.8 ± 34 minutes, with longer times in altered gut or patients with a BMI > 25 [30, 36]. Tube life span can range between 1 to 2 years, but replacement occurs much earlier because of degradation and malfunction; 27 % require exchange or removal by 60 days; however, Lim et al. had a mean duration of 8 months, alluding to the ability of jejunal tubes to remain patent with appropriate care and management [23, 24, 55].

This study is the first meta-analysis exploring technical feasibility and adverse effects of endoscopic jejunal feeding, as such gives credence to the existing literature and what is known that endoscopic jejunal tube placement can be placed with high fidelity and may be a viable source of nutrition in a wide range of clinical indications. We were able to include a wide range of studies since inception, making this a comprehensive review. Procedure details and patient characteristics were delineated. Our sub-group analysis includes device-assisted data for jejunal feeding for endoscopists in the modern era. Perhaps future studies can improve TS by considering ultrasound-guided placement.

Our meta-analysis has several limitations as well, most of which are inherent to any meta-analysis. Heterogeneity was high in most of our analyses, possibly from technique variation, endoscopist expertise, clinical indication, and type/size of tubes used). We could not calculate the TS as all studies did not uniformly report the number of successful placement attempts. A jejunal conduit can be placed for feeding or venting but was only defined in one study [43]. Clinical success was defined as successful initiation and tolerance of feeds that were often started between four and not more than 24 hours after successful placement, but this can vary as the tube may initially be left unclamped to vent the small bowel and decompress the insufflated air. A few studies defined technical success as successful placement and tolerance of feeds. Additionally, many studies did not require a second-look procedure to confirm placement. The majority of included studies were retrospective and small, and our findings require more extensive comparative data, but the potential for publication bias cannot be excluded due to a lack of negative studies. Despite successful placement in a few reports, our study results are not generalizable to the pediatric population or pregnant women [6, 7]. Additionally, only a few studies reported outcomes in obese patients, pancreatitis, limiting the clinical utility of these findings. Zopf et al., Fan et al., and Nishiwaki et al. are the only studies comparing DPEJ and PEG-J; however, the heterogeneous reporting precludes a pooled analysis [48, 56–58]. Follow-up data for clinical success and true jejunal feeding longevity lack, which is the duration from insertion to replacement, and does not necessarily reflect time-to-failure were additional limitations in accruing follow-up data. Lastly, patient selection is an important consideration to optimize the expected outcome.

Conclusions

Our analysis shows that jejunal feeding by DPEJ or PEG-J has high clinical and technical success with good patient tolerance and safety outcomes with a similar technical and clinical success profile. We found that DPEJ had fewer malfunction rates and more successful placement in cases of altered anatomy, although it was associated with higher peri-procedural major adverse events. The use of balloon enteroscopy enhanced its performance, suggesting a safe approach for future studies. PEG-J can be used concurrently for decompression and is technically less challenging, with higher placement rates in native anatomy. More prospective and head-to-head studies are needed to characterize the utility of each jejunal feeding procedure.

Competing interests

The authors declare that they have no conflict of interest.

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