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 non-nutrient 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 parenteral 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,” “PEG,” “PEG-J,” “PEJ,” 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 Quinteyva 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 (Bios tat, Englewood, New Jersey, United States). Pooled estimates and corresponding 95% confidence intervals (CI) for dichotomous variables were calculated using the random-effects inverse variance/De rSimonian-Laird method [16].

Heterogeneity was measured by Cochrane Q and I² 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 ≤ 0.05 combined with asymmetry in the funnel plots was used to measure significant publication bias, and if P < 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, I² 73.1%), while PEG-J – three studies, 138 patients had a pooled TS of 94.4% (CI, 85.5–97.9, I² 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, I² 12.7%), while PEG-J – five studies, 241 patients had a pooled CS of 98.7% (CI, 95.5–99.6, I² < 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%, I² 77.8%), while PEG-J – five studies, 241 patients had a pooled malfunction rate of 23.6% (CI, 7.5–54.1, I² 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, I² 49.4%), while PEG-J – five studies, 241 patients had a pooled...
| 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 translumination (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 translumination (3) | N/A |
| Mellert 1993 [42] | Prospective, single-center, Jan 1990 – Jun 1992, Germany | 44 | DPEJ | 200-cm-long endoscope (Fujinon EN7-MR2) | Modified Gauderer and Ponsky technique | No | Local anesthesia/sedation | Yes Mezlocillin 2 gm before procedure | PEG kit (PEG Universal Intestinal, Fresenius, FRG) | N/A | • No translumination (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 translumination | 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-100) | Shike modification | No                 | Local anesthesia | N/A              | PEG tube (MIC PEG, Ballard Medical Products, Draper, Utah) | 20-Fr PEG tube | ▪ No translumination (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                        | N/A                        |
| Shetzline 2001 [28] | Prospective, single-center, < 2001, USA | 7                 | DPEJ           | Push enteroscope (VS3 3430, Pentax, Orangeburg, NY) | Modified Gauderer and Ponsky technique | Yes               | 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                                                       | N/A               | Yes               | Cefazolin 1 gm IV prior to procedure | Pull-type PEG kit (Microvasive Endoscopy, Boston Scientific Corp., Natick, Mass) | 24-Fr PEG tube (24) 20-Fr PEG tube (2) | ▪ No translumination (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                 | Yes Cefazolin or Clindamycin | N/A              | 20-Fr PEG tube | ▪ No translumination (3) ▪ Inability to pass endoscope due to anatomy (1) | N/A |

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| 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) |
|------------|--------|-------------------|----------------|------------------------|--------------------|-------------------|-----------------|-------------------------|-----------------|---------------------------|-----------------------------|-----------------------------|
| Maple 2005 [45] | Retrospective, multicenter, consecutive, January 1996 – August 2004, USA | 286 | DPEJ | N/A | Modified Gauder and Ponsky technique | No | Local anesthesia/Sedation | Yes | Cefazolin 1 gm IV | PEG tube kit (Kimberly-Clark/Ballard Medical Products, Draper, UT) | ▪ No transillumination/finger indentation (79) | ▪ Inability to pass scope to the jejunum (8) | ▪ Difficulty passing scope and no transillumination (6) | ▪ Adverse response to sedation (4) | ▪ Equipment failure (1) | N/A |
| Del Piano M 2008 [29] | Prospective, single center, consecutive, April 2003 – March 2004, USA | 9 | DPEJ | Pediatric video colonoscopy (Olympus PCF-160 AL, Olympus Medical System Corp., Tokyo, Japan) | Pull technique | No | N/A | N/A | PEG tube kit (Kimberly Clark, Ballard Medical Products, Draper, Utah, USA) | 20-Fr PEG tube | ▪ No transillumination | 20 |
| 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 translumination | 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 |
| 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, CA) | 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 endoscope (Fuji non 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 |
| 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 (MICKEY gastrostomy tube; Hal-\_yard, Alpharetta, Georgia, USA) | Native Gut (3): inability to advance overtube, inability to advance the instrument due to anatomy, no translumination | 20-Fr PEG tube | 20 ± 10 |
| Bernardes 2017 [37] | Retrospective, single-center, January 2010 – February 2016, USA | 23                | SBE-DPEJ        | SIF-Q180 endoscope (Olympus, Tokyo, Japan) | Modified Gauder and Ponsky technique | No | Sedation | Yes 1 gm IV ceftriaxone before the procedure | N/A | 20-Fr | Inadequate translumination (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 anesthesia (27), • Sedation (27) | Yes | N/A | • 10-Fr (1), • 16-Fr (8), • 18-Fr (2), • 20-Fr (41) | None | 23 ± 10 |
| Author/Year | Design | Total patients (n) | Procedure type | Endoscope manufacturer | Reported technique | Use of Fluoroscopy | Anesthesia Used | Peri-procedural Antibiotics | Size of the tube (PEG, PEG-J, and DPEJ) | Mechanisms for unsuccessful placement | Procedure time – minutes (mean ± SD) | Successful placements | Non-successful placements |
|-------------|--------|--------------------|----------------|------------------------|-------------------|-------------------|-----------------|---------------------------|------------------------------------------|------------------------------------------|----------------------------------------|-------------------------------|-----------------------------|
| Kirstein 2018 [39] | Retrospective, single-center, 2009–2015, Germany | 39 | PEG-J | N/A | Modified Gauder and Ponsky technique | Yes | N/A | N/A | 24-Fr PEG tube (EndoVive Safety, Boston Scientific, Natick, Mass) | Not transluminal tube insertion, inability to identify satisfactory location for insertion | 27.7 ± 6.1 | 60.7 ± 34.6 | 71.4 ± 37.8 |
| Ridtitid 2018 [38] | Retrospective, single-center, 2010–Jan 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) | Inadequate transluminal tube insertion, inability to localize appropriate spot for tube placement | N/A | N/A | N/A |
| Simoes 2018 [40] | Retrospective, single-center, Jan 2005–March 2015, USA | 452 | PEG-J | N/A | Shike modification | N/A | N/A | N/A | Pediatric colonoscope or adult retrograde endoscopy | Inadequate transluminal tube insertion, inability to localize appropriate spot for tube placement | 20-Fr PEG tube | 60.7 ± 34.6 | 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, Multi-center, 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, cerebrovascular accident; DPEJ, direct percutaneous endoscopic jejunostomy; Fr, French; GI, gastrointestinal; IV, intravenous; J-tube, jejunostomy tube; N/A, not applicable; PEG, percutaneous endoscopic gastrostomy; PEG-J, percutaneous endoscopic jejunostomy; PEG-J, jejunal extension through PEG; SD, standard deviation.
| 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/de-attachment of the tubes |
| Shike 1991 [41] | N/A | None | - Post procedure fever (1) | - Fever (1) | None |
| Mellert 1993 [42] | None | None | - Tube dysfunction/breakage (5) - Jejunal ulcer (1) - Local wound infection (3) | - Jejunal ulcer (2) - Wound infection (3) - Tube dysfunc- tion/breakage | None |
| 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) | - Bowel Obstruction and volvulus (1) | None |
| Barrera 2001 [26] | N/A | 3 deaths from primary disease | - Colonic perforation with peritonitis (1) | - Persistent ileus (1) | None |
| Shetzline 2001 [28] | None | 1 from infection | - Infection (1) | - Infection (2) | None |
| Varadarajuulu 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 |
| 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)  
• Jejunal-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)  
• 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)  
• Jejunal Volvulus (2)  
• Sepsis (1)  
• Peristomal infection  
• Pain | • Necrotizing fasciitis (1)  
• Jejunal obstruction (1)  
• Jejunal Volvulus (2)  
• Sepsis (1)  
• Peristomal infection  
• Pain | • Tube occlusion/ degradation (4)  
• Fistula after DPEJ removal (1)  
• Aspiration  
• Peristomal infection |
| 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  
• Pain | • Tube occlusion/ degradation (4)  
• Fistula after DPEJ removal (1)  
• Aspiration  
• Peristomal infection |
| Moran 2009 [32] | None | 14 deaths | • Bilious 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 vomiting (1) | • Aspiration with pneumonia (1)  
• Gastropareisis (1)  
• Aspiration |
| Song 2012 [46] | None | None | None | • Peristomal cellulitis (1)  
• Peristomal cellulitis (1) | • 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) |
| Author/ Year | Mecha- nisms for failure after initi- ating feeds | Major ad- verse event – All-cause mortality | Major adverse event requiring inter-vention – sur- gery or repeat endoscopy | Minor adverse events | Short term (<30 days) | Long term (>30 days) |
|--------------|-----------------------------------------------|----------------------------------------|---------------------------------|-------------------|-------------------|-------------------|
| Lim 2015 [47] | None | 27 death from under-lying dis- ease | ▪ Tube blockage with replacement (6)  
▪ Gastric perfora- tion (1)  
▪ Jejunal perforation during tube replace- cement (1) | ▪ Peristomal infec- tion (3)  
▪ Leakage around the stoma (4)  
▪ Minor bleeding (2)  
▪ Aspiration (1) | ▪ Gastric Perfora- tion (1)  
▪ Peristomal infec- tion (3)  
▪ Peristomal leak- age (4)  
▪ Minor bleeding (2)  
▪ Aspiration (1) | ▪ Tube blockage with replacement (6)  
▪ Jejunal perfora- tion during tube replace- cement (1) |
| Velázquez- Aviña 2015 [35] | None | None | ▪ Accidental remov- al with immediate replacement (1) | ▪ Jejunostomy site infection (1) | None | 5 planned remov- als  
▪ One accidental removal with im- mediate replace- ment |
| Al-Bawar- dy 2016 [36] | N/A | None | ▪ Gastric Interposi- tion (1) | ▪ Abdominal Hema- toma (2) | ▪ Limited GI bleed- ing from PEJ site ulceration/cellu- litis (4)  
▪ PEJ tube kink (1) | N/A |
| Bernardes 2017 [37] | None | None | ▪ Jejunal perforation during the proce- dure (1) | None | None | ▪ Accidental exter- iorization of the PEJ bumper (2) at 10 and 13 months |
| Strong 2017 [24] | None | None | ▪ Tube dislodg- ement (10)  
▪ Bowel Obstruction (1)  
▪ Volvulus (1)  
▪ Repeat endoscopy with tube ex- change (16) | ▪ Aspiration event during induction of general anes- thesia (1)  
▪ Superficial wound infection at jeju- nostomy site treated with oral antibiotics (1) | ▪ Leakage around the tube with skin maceration (1)  
▪ Tube blockage without need for repeat endos- copy (1)  
▪ Tube dislodge- ment with repeat endoscopy and replacement (1)  
▪ Tube blockage (4)  
▪ Tube dislodg- ment (10)  
▪ Bowel Obstruc- tion (1)  
▪ Volvulus (1)  
▪ Permanent Re- moval (4) | ▪ Re-endoscopy (16)  
▪ Tube exchange (17)  
▪ Tube Leakage (10)  
▪ Tube blockage (4)  
▪ Tube dislodge- ment (10)  
▪ Bowel Obstruc- tion (1)  
▪ Volvulus (1)  
▪ Permanent Re- moval (4) |
| Kirstein 2018 [39] | N/A | N/A | ▪ Pneumoperito- neum (1)  
▪ PEG-j dislocation/ dysfunction (26)  
▪ PEG dysfunction (5) | ▪ Local infection (2)  
▪ Obstipation (2) | N/A | N/A |
| 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 dislocation (52) ▪ Buried Bumper (2) | ▪ Cellulitis (21) ▪ Intolerance to feeds (10) | ▪ Jejunal tube clogging (7) ▪ Jejunal tube kinking (10) ▪ J-tube dislocation (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 Syndrome (1) ▪ Peristomal infection (25) ▪ Leakage (30) ▪ Diarrhea (11) ▪ Tube dysfunction (3) | ▪ Bleeding ▪ Small bowel obstruction ▪ Intra-abdominal abscess ▪ 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] | Pneumonia with respiratory failure (1) | ▪ Upper GI bleeding (3) ▪ Colocutaneous fistula (2) ▪ Pneumoperitoneum (1) ▪ Tube dislocation (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 dislocation (8) ▪ Diarrhea (7) ▪ Vomiting (6) ▪ Granuloma (4) ▪ Buried bumper syndrome (2) ▪ Ileus (2) |

BMI, body mass index; cal, calories; CVA, cerebrovascular accident; DPEJ, direct percutaneous endoscopic jejunostomy; Fr, French; GI, gastrointestinal; IV, intravenous; J-tube, jejunal 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 (mean ± SD) | 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 | Native gut (10) | None | | Technical success | Tube feeds started the next day |
| | | | | | | Severe neurologic impairment with aspiration and need for long-term enteral nutrition | | | Procedure-related complications | |
| Shike 1987 [21] | DPEJ | 11 | NR | N/A | N/A | Nutritional support in patients with GI malignancy | None | | Technical success | 900–2400 calories/day |
| | | | | | | | | Procedure-related complications | Ability to provide adequate enteral nutrition | |
| Kaplan 1989 [22] | PEG-J | 23 | 67 ± 11 | 23/0 | 141 | Recurrent aspiration pneumonia (23) | Native Gut (22) | | Technical success | Placemen |
| | | | | | | | | Procedure-related complications | of the PEJ tubes | |
| | | | | | | | | Acute and chronic complications | Overall survival of the patients after PEJ placement | |
| Shike 1991 [41] | DPEJ | 6 | 60 ± 5 | 2/4 | 180 | None | Native Gut (6) | | Technical success | Tube feeds started the next day |
| | | | | | | | | Procedure-related complications | 75 to 100 mL/hr | |

- Duodenal / gastric outlet obstruction (2)
- Aspiration (2)
- Gastric drainage (1)
- Gastric dysmotility (1)
- Altered Gut (10)
- Gastric carcinoma (5)
- Pancreatic cancer s/p Whipple (2)
- Non-operative pancreatic cancer with prior PEG (2)
- Esophagectomy and gastric pull up (1)
| 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) ▪ Esophagogastroscopy (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 canceroma/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) ▪ Gastrjejunostomy (4) ▪ Esophageal resection/gastric pull up (3) ▪ Gastrectomy (1) | ▪ Technical success of the procedure ▪ Procedure-related complications ▪ Need for reinter-vention for jejunal access | 2835–9425 kJ/day Rate 60–125 mL/hour |
| Author/Year | Procedure type | Total patients (n) | Age (mean±SD) | 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) | Altered Gut (4) | • 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 |
| Varadara- julu 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) | Altered Gut (16) | • 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 (2) • Aspiration (4) • Chylous leak (2) • Prolonged ileus (2) | None | Altered Gut (25) | • Technical success of the procedure • Procedure-related complications • Enteral feeding • Overall outcomes | Tube feeds started at 24 hours Mean 1667 Kcal/day (1500–3180) |
| Author/Year | Procedure type | Total patients (n) | Age | 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/included ▪ 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 | ▪ Gastroparesis (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 |
| 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) | Altered gut (1) | ▪ Weight before and after 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 gastrosomy insertion was inappropriate | Native Gut (19) | Altered Gut (21) | ▪ Technical success | N/A |
| Aktas 2012 [33] | SBE-DPEJ | 11 | 54 ± 17 | 7/4 | N/A | N/A | ▪ Recurrent aspiration (5) | Native gut (8) | Prior PEG or PEG-J in 4 patients | ▪ Successful placement of DPEJ | N/A |
| Song 2012 [46] | DBE-DPEJ | 10 | 59 ± 19 | 2/8 | 30 | 25 ± 6.25 | ▪ Gastroparesis (4) | Native gut (6) | ▪ Pancreaticoduodenectomy (1) | ▪ Successful placement of DBE assisted DPEJ | N/A |
| 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 | 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) | Native gut (45) | Altered gut (30) | Prior PEG tube (29) | 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) | Native gut | Altered gut | Status post-gastroctomy or gastric pull up (6) | Tube feeds started at 12 hours |
| | | | | | | | Status post-gastroctomy or gastric pull up (6) | Complex fistula (6) | Altered gut | Status post-gastroctomy or gastric pull up | Placement of DPEJ |
| | | | | | | Necrotizing Pancreatitis (7) | with bowel obstruction (6) | | | Subsequent usage of DPEJ for enteral feeding |
| | | | | | | Sarcoma with bowel obstruction (1) | | | | Planned and unplanned removal |
| 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-Bawar-ndy 2016 [36] | DBE-DPEJ | 94 | 55 ± 20 | 39 / 55 | 30 | 2.3 ± 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) | Altered gut (36) | Placement of DPEJ | 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 |
| 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) | Native gut (2) | Altered Gut (57) | Placement of DPEJ | 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) | Overall survival | N/A |
| Ridtitid 2018 [38] | PEG-J | 102 | 51 ± 18 | 31 / 71 | 495 ± 173 | | Intolerance to eating | Native Gut (86) | Altered Gut (16) | Short and long term complications of related to PEG-J placement | Tube feeds initiated 12–24 hours 1.5 cal/mL daily |
| 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 esophageal 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 re-intervention  
▪ Short term and long term adverse events | N/A |
| 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 | Native gut (61) | Altered Gut (54) | Comparison of survival outcomes in PEG and DPEJ | Tube feeds initiated the day after the procedure |

BMI, body mass index; cal., calories; CVA, cerebrovascular accident; DPEJ, direct percutaneous endoscopic jejunostomy; Fr, French; GI, gastrointestinal; IV, intravenous; J-tube, jejunostomy tube; N/A, not applicable; PEG, percutaneous endoscopic gastrostomy; PEG-J, jejunal extension through PEG; SD, standard deviation.
major adverse events rate of 1.3% (CI, 0.3–5.2, I² < 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, I² 85.2%), while PEG-J – four studies, 202 patients had a pooled minor adverse events rate of 25.0% (CI, 14.3–40.0, I² 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%, I² 57.8%) and second attempt successful placement at 90.2% (95% CI, 75.0%–96.7%, I² < 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, I² < 0.001), while non-device-assisted enteroscopy had a pool TS of 86.9% (CI, 82.1–90.6, I² 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, 1.4–14.4, I² 38.9%), while non-device-assisted enteroscopy had a malfunction rate of 14.4% (CI, 9.3–21.7, I² 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, I² < 0.001), while non-device-assisted enteroscopy had a major adverse event rate of 4.5% (CI, 2.9–7.1, I² 53.4%). The difference between both was not statistically significant, P = 0.7.
Minor adverse events rate: DPEJ by device-assisted enteroscopy had a minor adverse event rate of 5.5% (CI, 1.7–16.3, I² 37.6%), while non-device-assisted enteroscopy had a minor adverse event rate of 19.3% (CI, 13.4–27.0, I² = 85.5%). There was a statistical significance, P = 0.03.

Altered anatomy – DPEJ TS was 87.8% (CI, 84.9–90.2, I² < 0.001) and PEG-J was 81.6% (CI, 58.1–93.4, I² < 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, I² 36.4%) and PEG-J was 97.4% (CI, 90.0–99.3, I² < 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 I² was moderately consistent >75% across outcomes suggesting considerable heterogeneity of our sample.
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-
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 nasogastic 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

| Group by Endoscopic Approach | Study name | 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                        | Akta 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                        | Bernades 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                       | Rikitidit 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    |

Figure 3: Forest plot of pooled DPEJ and PEG-J malfunction rates, major and minor adverse events. Major 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 than 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.

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### Minor adverse events

| Group by Endoscopic Approach | Study name       | Event rate | Statistics for each study | Event rate and 95% CI |
|------------------------------|------------------|------------|---------------------------|-----------------------|
|                              |                  | Event      | Lower Limit               | Upper Limit           | Z-Value   | P-Value   |
| 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                         | Akts 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                         | Veláquez-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                         | Kirstin 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                        | Ponsy 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     |

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