Clinical Outcomes of 3D Laparoscopic Hiatal Hernia Repair Either Combined With Toupet Fundoplication or Nissen Fundoplication: A Comparative Analysis

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AIM: This study aimed to perform a rigorous comparison of perioperative and functional outcomes between the 3D laparoscopic Toupet (270° posterior partial fundoplication) vs. Nissen (360° total fundoplication) for hiatal hernia (HH) repair in gastroesophageal reflux disease (GERD) patients.

METHODS: This retrospective cohort study included 103 patients with HH and GERD who underwent surgery between January 2020 and May 2024. Patients were divided into two groups based on surgical technique: the Toupet group (n = 53) and the Nissen group (n = 50). Outcomes included surgical metrics, pre/postoperative high-resolution manometry, 24-hour pH-impedance, gastroesophageal reflux disease symptom questionnaire (GERD-Q) and gastroesophageal reflux disease health-related quality of life (GERD-HRQL) scores, and complications. Multivariable regression adjusted for baseline differences.

RESULTS: The Toupet group demonstrated significantly shorter time to first postoperative oral intake ($p = 0.012$) and hospital stays ($p = 0.023$) compared to the Nissen group. At 6 months postoperatively, both groups showed significant increases in minimum lower esophageal sphincter (LES) resting pressure and respiratory mean values, along with decreases in reflux-related parameters and ineffective swallowing ratio ($p < 0.001$). Intergroup comparison revealed that the Toupet group had lower minimum LES resting pressure, respiratory mean LES pressure, and ineffective swallowing ratio, but higher 24-hour reflux episodes, percentage acid exposure time, and mean DeMeester scores than the Nissen group ($p < 0.001$). At 1 year postoperatively, both groups exhibited significant improvements in GERD-Q and GERD-HRQL scores ($p < 0.001$), with no intergroup differences observed ($p > 0.05$). The Toupet group had significantly lower overall complication rates ($p = 0.031$) and a lower incidence of dysphagia than the Nissen group ($p = 0.019$). Multivariable regression analyses confirmed that the Toupet procedure was an independent predictor for shorter time to first postoperative oral intake ($p = 0.015$), shorter hospital stays ($p = 0.017$), and lower overall complication rates ($p = 0.020$).

CONCLUSIONS: In summary, when performed with 3D laparoscopy, Toupet and Nissen fundoplication show distinct and meaningful clinical profiles. Nissen fundoplication is the preferred option for achieving maximal anti-reflux efficacy in patients with normal esophageal motility, whereas Toupet fundoplication is preferred for minimizing postoperative dysphagia and enhancing rapid recovery, particularly in cases with impaired or borderline motility.

Keywords: hiatal hernia; gastroesophageal reflux; laparoscopy; fundoplication; treatment outcome

Introduction

Gastroesophageal reflux disease (GERD), characterized by retrograde flow of gastric contents into the esophagus, leading to symptomatic distress or complications, is increasingly prevalent worldwide and significantly compromises quality of life [1–3]. In patients with moderate-to-large hiatal hernia (HH), poor response to medical therapy, or GRED-related complications, laparoscopic HH repair combined with fundoplication is the preferred surgical modality [4].

Among available fundoplication techniques, Nissen fundoplication (360° wrap) is regarded as the standard procedure due to its established anti-reflux efficacy. However, its use is limited by associated postoperative adverse events, including dysphagia, abdominal distension, and impaired ability to belch [5]. To address these functional sequelae, the Toupet procedure (270° posterior partial fundoplication) has been widely adopted, based on the rationale that preserving posterior space may better minimize interference with esophageal peristalsis and reduce the risk of postoperative dysphagia [6].

Conventional laparoscopy provides only a two-dimensional planar view, which limits depth perception and spatial orientation. However, 3D systems efficiently address this limitation by restoring stereoscopic vision. Evidence from a Meta-analysis reveals that 3D systems offer tangible clinical benefits over 2D laparoscopy, including shorter operative time, reduced intraoperative blood loss, and reduced length of hospital stays. Particularly during laparoscopic

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HH repair, 3D visualization has been linked to shorter operative time and improved surgical precision compared with a 2D system [7]. However, study comparing Nissen and Toupet procedures report comparable reflux control, with the Toupet technique associated with better functional outcomes, including lower rates of postoperative dysphagia and improved quality of life [8].

Whether these two surgical approaches offer distinct clinical advantages when performed with 3D laparoscopy, particularly with respect to perioperative outcomes, objective reflux parameters, patient-reported measures, and complication rates, has not been comprehensively investigated. Therefore, this retrospective study aims to comprehensively compare outcomes of 3D laparoscopic HH repair combined with either a Toupet or a Nissen fundoplication. By combining traditional clinical endpoints with objective physiological parameters and validated subjective patient-reported outcomes, this study seeks to provide robust evidence guiding individualized surgical selection within the context of advanced 3D laparoscopic technology.

Methods

Study Population

This retrospective cohort study included 103 patients with HH complicated by GERD. The patients underwent 3D laparoscopic HH repair combined with fundoplication at the Jinhua Municipal Central Hospital, China, between January 2020 and May 2024. They were divided into two groups based on the surgical approach used. The Toupet group (n = 53) received 3D laparoscopic HH repair combined with 270° posterior partial fundoplication, and the Nissen group (n = 50) underwent 3D laparoscopic HH repair combined with 360° total fundoplication.

The study obtained ethical approval from the Institutional Ethics Review Board of Jinhua Municipal Central Hospital (No.2025-284) and strictly adhered to the principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participating patients before enrollment.

Inclusion and Exclusion Criteria

Patient selection followed predetermined inclusion-exclusion criteria. Inclusion criteria included (1) age between 18 and 75 years; (2) diagnosis of HH according to the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) Guidelines for Hiatal Hernia (2013) [9], and GERD diagnosed according to the Chinese Expert Consensus Statement on Gastroesophageal Reflux Disease (2014) [10], with both confirmed clinically; (3) preoperative 24-hour esophageal pH monitoring demonstrating pathologic acid reflux (DeMeester score >14.7); (4) presence of typical reflux symptoms unresponsive to or dependent on proton pump inhibitor (PPI) therapy; (5) undergoing first-time HH surgery and anti-reflux procedures.

The exclusion criteria comprised (1) history of upper abdominal surgery; (2) preoperative high-resolution manometry (HRM) indicating achalasia or other major esophageal motility disorders; (3) intraoperative identification of shortened esophagus requiring Collis gastroplasty; (4) severe cardiopulmonary dysfunction or coagulopathy; (5) known malignancy; and (6) incomplete clinical information or follow-up data.

Surgical Methods

All surgical procedures in both patient groups were conducted by the same team of experienced surgeons. The choice between Toupet and Nissen fundoplication was not randomized and was based on a standardized preoperative assessment process and collective decision-making by the surgical team. Esophageal motility was considered the critical determinant, with Toupet partial fundoplication preferentially applied to patients demonstrating significantly impaired peristalsis on high-resolution esophageal manometry, such as an effective peristalsis rate <60% or evident ineffective peristalsis, to reduce the risk of postoperative dysphagia. Furthermore, the anatomical and functional conditions of the gastric fundus were carefully evaluated; those with poor fundus mobility, for example, due to inflammation or obesity, in whom a tension-free 360° circumferential wrap could not be effectively achieved, were more likely to undergo Toupet fundoplication. In borderline cases, or when pre- and postoperative outcomes were unclear, the final choice of surgical procedure was determined by the senior surgeon according to comprehensive clinical assessment and surgical experience.

General Preoperative Preparation

All procedures were performed under general anesthesia with patient placed in the supine position with legs apart, and the lower limbs were abducted no more than 30° to avoid femoral nerve injury, and in a slight reverse Trendelenburg position (15–20° head-up tilt). A standard five-port laparoscopic approach was established using a 3D HD laparoscopic system to ensure all surgical team members maintained normal stereoscopic vision and depth perception. A 10–12 mm observation port was placed 2 cm cephalad or caudad to the umbilicus for insertion of the 3D laparoscope. A 12-mm primary working port was positioned at the xiphoid level along the left midclavicular line, and three 5-mm accessory working ports were deployed in the right subcostal region 2 cm below the costal margin, the midline infraxiphoid region (for liver retractor placement), and the left anterior axillary line at the level of the umbilicus.

Furthermore, a 3D high-definition laparoscopic platform (Storz or Olympus) was employed in all cases, along with standard advanced laparoscopic instruments, including ultrasonic energy devices (Harmonic Ace), needle holders, atraumatic graspers, and liver retractors (Nathanson or fan-shaped retractors). After establishing pneumoperitoneum

and placing the trocars, the 3D visualization system was configured, and the surgeon, assistant, and camera operator used system-compatible 3D eyewear or glasses. During this configuration, the camera operator inserted the 3D laparoscope through the observation port and adjusted it for optimal visualization. Surgical was initiated only after confirmation of stable, clear, non-overlapping 3D imaging and adequate depth perception by all team members.

Common Surgical Steps: HH Repair

For both surgical techniques, a standardized HH repair was conducted, including reduction of hernia contents, excision of the hernia sac, mobilization of the distal esophagus, and crural closure. Upon entering the peritoneal cavity, a systematic exploration was conducted and the left lobe of the liver was elevated using a liver retractor to properly expose the esophageal hiatus. The hernial sac, its contents (typically the gastric fundus and body), and the diaphragmatic crura were clearly identified. The herniated region was carefully reduced into the abdominal cavity, and the sac was dissected and removed. The distal esophagus was then mobilized to ensure a tension-free intra-abdominal esophageal segment measuring 2.5–3.0 cm, with selective division of 1–2 short gastric vessels, as needed, to facilitate adequate fundic mobilization. Esophageal hiatus was repaired with 2–3 stitches of interrupted non-absorbable sutures to approximate the crura, enabling a secure closure without excessive construction that might lead to postoperative esophageal stricture.

Fundoplication Following HH Repair

In the Toupet group, fundoplication was performed after successful HH repair. The posterior wall of the gastric fundus was fully mobilized, particularly after selective division of short gastric vessels when required, enabling tension-free retroesophageal passage of the fundus. The mobilized posterior fundus was then brought through the retroesophageal window to the right side of the esophagus, with its left portion positioned along the left posterolateral aspect and the right portion along the right posterolateral aspect of the distal esophagus, creating a ~270° posterior partial wrap while leaving the anterior esophageal wall unwrapped.

Finally, the wrap was fixed by suturing the edges of the fundic cuff to the esophageal wall and the adjacent diaphragmatic crura using interrupted non-absorbable sutures. A loose "collar" configuration was maintained, verified intraoperatively by smooth passage of a bougie of $\geq$52 Fr alongside wrap, to alleviate the risk of postoperative dysphagia.

Nissen 360° Fundoplication (Total Fundoplication)

In the Nissen group, total fundoplication was performed after successful HH repair. The gastric fundus, particularly the upper greater curvature, was extensively mobilized, often with division of 2–3 short gastric vessels to enable tension-free circumferential wrap around the esophagus. The posterior fundus was passed through the retroesophageal window to the right side of the esophagus, and the anterior fundus was then pulled to the right, merging with the posterior fundus behind the esophagus to create a 1.5–2.0 cm "collar" 360° cuff around the distal esophagus. The fundoplication was secured using 2–3 interrupted non-absorbable sutures, with the key suture incorporating the full-thickness gastric wall and the esophageal muscular layer to maintain stability and prevent slippage. The wrap was calibrated intraoperatively, confirming a "floppy" Nissen by the smooth passage of a $\geq$56–60 Fr bougie alongside the esophagus, minimizing risk of postoperative dysphagia.

Completion of Procedure

Upon completion of the fundoplication, the surgical field was carefully inspected. It was irrigated to confirm hemostasis, assess adequate perfusion of the wrapped gastric segment, and ensure that neither the hiatal repair nor the wrap was under excessive tension. According to our hospital's procedures, a peritoneal drainage tube is routinely placed next to the esophageal hiatus and brought out through the right-side trocar puncture site. After evacuation of the pneumoperitoneum, final instrument and sponge counts were confirmed, and all trocar sites were closed in layers.

Observation Indicators

Baseline Characteristics

Demographic and clinical data included gender, age, body mass index (BMI), type of HH, symptom duration, family history of GERD, and comorbid hypertension, diabetes mellitus, and cardiovascular disease.

Perioperative Outcomes

Perioperative metrics recorded were surgical time, intraoperative blood loss, time to postoperative oral intake, and length of postoperative hospital stays.

HRM and 24-hour Esophageal pH-impedance Monitoring

All patients underwent HRM and 24-hour esophageal pH-impedance monitoring preoperatively and 6 months after the procedure. Medications that affect esophageal motility were discontinued at least 48 hours before testing, and PPIs at least 72 hours.

HRM was conducted according to the standardized clinical protocol of the Temple University Motor Lab. A solid-state manometry catheter (MSC-1286, Medtronic Inc., Shoreview, MN, USA) with 36 circumferential pressure sensors spaced at 1 cm intervals and 18 impedance sensors at 2 cm intervals was inserted transnasally into the stomach after a minimum 6-hour fast, with the patient lying in a supine position. The catheter was adjusted to precisely identify the upper esophageal sphincter (UES), lower esophageal sphincter (LES), and proximal stomach on the monitor.

Following a 5-minute equilibration to body temperature, a 30-second baseline recording was obtained. After that, the patient underwent ten single 5-mL swallows of room-temperature saline at 30-second intervals.

Mean resting LES pressure and nadir LES pressure during swallowing were analyzed, and esophageal body motility was assessed according to the Chicago Classification v3.0 criteria [11]. Swallow was classified as ineffective if they exhibited a distal contractile integral (DCI) between 100–450 mmHg·s·cm (weak peristalsis), a DCI <100 mmHg·s·cm (failed peristalsis), or a contraction front velocity (CFV) >9 cm/s (rapid contractions). The rate of ineffective swallow was calculated as follows: (the number of ineffective swallows / the total swallows) × 100%.

For 24-hour esophageal pH-impedance monitoring, a combined pH-impedance catheter probe (UPS-2020, MMS, Enschede, Netherlands) was inserted transnasally, with the pH sensor positioned 5 cm proximally to the upper margin of the LES. A reference electrode was placed on the anterior chest wall, and data were recorded using an external data logger over a 24-hour period. Patients were directed to maintain their normal daily activities and diet during monitoring, while avoiding foods with a pH <5. Primary parameters analyzed included total esophageal acid exposure time (percentage of total time with pH <4, the number of reflux episodes (defined as a decline in pH below 4 followed by recovery, and the DeMeester score, which is a composite score integrating six parameters, such as percentage acid exposure time in total, upright, and supine positions; total number of acid reflux episodes; number of episodes lasting longer than 5 minutes; and the duration of longest reflux [12]. A DeMeester score ≥14.72 indicated pathological acid reflux. Consistent with clinical practice, reflux severity was further categorized as normal (<14.72), mild (14.72–50), moderate (51–100), and severe (>100).

Gastroesophageal Reflux Disease Symptom Questionnaire (GERD-Q) Score

The GERD-Q questionnaire was administered at baseline and at 1 year postoperatively to assess severity the of GERD-related symptoms and their impact on daily activities over the preceding 7 days. The scale comprises six items, including positive predictors (frequency of heartburn and regurgitation), negative predictors (frequency of epigastric pain and nausea), and items evaluating functional impact (sleep disturbance due to reflux symptoms and the use of additional over-the-counter medication for symptom relief). Each item was scored according to symptom frequency: 0 points for no days, 1 point for 1 day, 2 points for 2–3 days, and 3 points for 4–7 days. For the negative predictor items (epigastric pain and nausea), scores were reversed to ensure that higher values uniformly indicate greater GERD burden (3 points for no days, 0 points for 4–7 days). The total GERD-Q score ranges from 0 to 18, with higher scores indicating more severe GERD symptoms and greater impairment of daily life [13]. Therefore, a reduction in the total score after surgery signifies clinical improvement.

Gastroesophageal Reflux Disease Health-related Quality of Life (GERD-HRQL) Score

The GERD-HRQL questionnaire was administered preoperatively and at 1 year postoperatively to evaluate the impact of typical GERD symptoms on health-related quality of life. This instrument consists of 10 items: six items pertaining to heartburn, two addressing dysphagia, one assessing bloating, and one item assessing the impact of medication use. Each item is rated on a 6-point Likert scale from 0 to 5, where 0 represents "No symptoms" and 5 represents "Incapacitating symptoms" or "Constant symptoms" (depending on the item's phrasing). The total score ranges from 0 to 50, with higher total scores indicating greater symptom burden and more severe negative impact on the patient's quality of life [14,15]. Therefore, a reduction in the total score after surgery signifies an improvement in GERD-specific health-related quality of life.

Postoperative Complications

Postoperatively, patients were followed for 1 year to document complications, including acid reflux, heartburn, dysphagia, and abdominal distension or inability to belch. These adverse events were recorded and compared.

Statistical Analysis

All statistical analyses were performed using SPSS version 26.0 (IBM Corporation, Armonk, NY, USA). The Kolmogorov–Smirnov test was used to assess the normality of continuous variables. Data conforming to a normal distribution were presented as mean ± standard deviation ($\bar{x}$ ± s), with between-group comparisons conducted using the independent samples *t*-test, and within-group comparisons via the paired samples *t*-test. Non-normally distributed data were expressed as median with interquartile range (Q1, Q3) and analyzed with the Mann–Whitney U test for between-group comparisons and the Wilcoxon signed-rank test for within-groups comparisons. Categorical variables were reported as frequencies and percentages [n (%)], with group differences determined using Pearson's Chi-square test with Yates' continuity correction or Fisher's exact test, as appropriate.

To ascertain whether postoperative differences were independently associated with the surgical technique rather than baseline characteristics, multivariable regression analyses were performed. Linear regression models were used for continuous outcomes and logistic regression for binary. Surgical group (Toupet vs. Nissen), age, BMI, duration of symptoms, and type of HH were incorporated as covariates in all models based on clinical relevance. Gender was excluded due to collinearity with other variables (variance inflation factor >5). Findings were reported as unstandard-

Table 1. Comparison of clinical characteristics between the two groups [$\bar{x} \pm s$, n (%)].

Characteristic/group	Toupet group (n = 53)	Nissen group (n = 50)	t/χ^2	p-value
Gender (male)	31 (58.49)	27 (54.00)	0.211	0.646
Age (years)	53.40 ± 6.83	55.60 ± 6.38	1.687	0.095
BMI (kg/m²)	23.62 ± 4.03	23.89 ± 3.06	0.381	0.704
Type of HH				
I	28 (52.83)	24 (48.00)	0.240	0.624
II	6 (11.32)	6 (12.00)	0.012	0.914
III	12 (22.64)	13 (26.00)	0.158	0.691
IV	7 (13.21)	7 (14.00)	0.014	0.907
Symptom duration (months)	22.63 ± 5.75	21.38 ± 6.28	1.054	0.294
Family history of GERD	9 (16.98)	9 (18.00)	0.019	0.892
Hypertension	15 (28.30)	12 (24.00)	0.246	0.620
Diabetes mellitus	8 (15.09)	8 (16.00)	0.016	0.899
Cardiovascular disease	4 (7.55)	5 (10.00)	0.008	0.660

BMI, body mass index; HH, hiatal hernia; GERD, gastroesophageal reflux disease.

Table 2. Comparison of perioperative indicators between the two groups [$\bar{x} \pm s$].

Group	Toupet group (n = 53)	Nissen group (n = 50)	t-value	p-value
Surgical time (min)	84.37 ± 15.26	86.44 ± 17.86	0.634	0.528
Intraoperative blood loss (mL)	34.75 ± 9.63	35.43 ± 9.98	0.352	0.726
Time to first postoperative oral intake (day)	1.57 ± 0.44	1.84 ± 0.62	2.560	0.012
Postoperative hospital stays (day)	4.14 ± 1.27	4.78 ± 1.53	2.315	0.023

ized regression coefficients (B) with 95% CIs for linear regression models and adjusted odds ratios (ORs) with 95% CIs for logistic regression models. All p-values were two-tailed, and statistical significance was defined at a p-value less than 0.05.

Results

Comparison of Baseline Clinical Characteristics Between the Two Groups

As detailed in Table 1, no statistically significant differences were observed between the Toupet and Nissen groups regarding gender, age, BMI, type of HH, symptom duration, family history of GERD, hypertension, diabetes mellitus, or cardiovascular disease ($p > 0.05$).

Comparison of Perioperative Outcomes Between the Two Groups

Patients in the Toupet group had significantly shorter postoperative hospital stays ($p = 0.023$) and a quicker resumption of oral intake ($p = 0.012$) than those in the Nissen group. However, no statistically significant differences were observed between the two groups in surgical time or intraoperative blood loss ($p > 0.05$, Table 2).

Comparative Analysis of Esophageal Function Between the Two Groups

Preoperatively, there were no statistically significant differences between the two groups in minimum LES resting pressure, respiratory mean LES pressure, number of 24-hour reflux episodes, ineffective swallowing ratio, percentage of 24-hour esophageal acid exposure time, or DeMeester score ($p > 0.05$). At 6 months postoperatively, both groups exhibited a significant increase in minimum LES resting pressure and respiratory mean LES pressure compared with baseline ($p < 0.001$), along with substantial reductions in 24-hour reflux episodes, ineffective swallowing ratio, 24-hour esophageal acid exposure time, and DeMeester score ($p < 0.001$).

Intergroup comparisons at 6 months revealed that the Toupet group had significantly lower minimum LES resting pressure, respiratory mean LES pressure, and ineffective swallowing ratio ($p < 0.001$), but significantly higher numbers of 24-hour reflux episodes, greater percentage of esophageal acid exposure time, and increased DeMeester score compared to the Nissen group ($p < 0.001$, Table 3).

GERD-Q Score and GERD-HRQL Score

Preoperatively, there were no statistically significant differences between the two groups in GERD-Q scores or GERD-HRQL scores ($p > 0.05$). At 1 year postoperatively, both groups exhibited significant improvements in GERD-Q and GERD-HRQL scores compared with baseline ($p < 0.001$), although no significant intergroup differences were observed at this time point ($p > 0.05$, Table 4).

Comparison of Postoperative Complications Between the Two Groups

At 1 year postoperatively, the overall complication rate was significantly lower in the Toupet group than in the Nissen group ($p = 0.031$). Specifically, no significant differ-

Table 3. Comparison of esophageal function indicators between the two groups [$\bar{x} \pm s$].

Group	Toupet group (n = 53)	Nissen group (n = 50)	t-value	p-value
Minimum LES resting pressure (mmHg)				
Before surgery	0.86 ± 0.24	0.85 ± 0.21	0.224	0.823
After surgery	16.34 ± 3.11 **	20.82 ± 4.43 **	5.967	<0.001
Respiratory mean LES pressure (mmHg)				
Before surgery	6.49 ± 1.54	6.41 ± 1.64	0.255	0.799
After surgery	19.69 ± 3.75 **	24.34 ± 4.52 **	5.695	<0.001
24-hour reflux episodes				
Before surgery	113.30 ± 21.88	114.66 ± 20.74	0.323	0.747
After surgery	19.55 ± 3.85 **	16.56 ± 3.13 **	4.310	<0.001
Ineffective swallowing ratio (%)				
Before surgery	18.57 ± 2.72	17.82 ± 2.64	1.419	0.159
After surgery	9.41 ± 1.83 **	13.63 ± 2.27 **	10.451	<0.001
Percentage of 24-hour esophageal acid exposure time (%)				
Before surgery	10.54 ± 2.38	10.62 ± 2.41	0.169	0.866
After surgery	3.56 ± 0.81 **	2.36 ± 0.42 **	9.355	<0.001
DeMeester score (points)				
Before surgery	43.13 ± 8.16	42.28 ± 8.63	0.514	0.609
After surgery	10.64 ± 2.79 **	7.31 ± 1.41 **	7.575	<0.001

LES, lower esophageal sphincter. Compared with the same group before surgery, **$p < 0.001$.

Table 4. Comparisons of GERD-Q and GERD-HRQL scores between the two groups [$\bar{x} \pm s$, Median (Q1, Q3)].

Group	Toupet group (n = 53)	Nissen group (n = 50)	t/Z-value	p-value
GERD-Q score (points)				
Before surgery	11.00 (9.00, 12.00)	10.00 (9.00, 11.25)	0.683	0.495
After surgery	6.00 (5.00, 7.00) **	6.00 (5.00, 7.00) **	0.372	0.710
GERD-HRQL score (points)				
Before surgery	19.26 ± 4.85	18.56 ± 4.42	0.764	0.447
After surgery	8.57 ± 2.18 **	7.82 ± 2.00 **	1.816	0.072

GERD-Q, gastroesophageal reflux disease symptom questionnaire; GERD-HRQL, gastroesophageal reflux disease health-related quality of life. Compared with the same group before surgery, **$p < 0.001$.

ences were found between the groups in the incidence of acid reflux, heartburn, or abdominal distension/inability to belch ($p > 0.05$). However, the incidence of dysphagia was significantly lower in the Toupet group than in the Nissen group ($p = 0.019$, Table 5).

Multivariate Analysis of Postoperative Recovery and Complications

The results of multivariable analyses are summarized in Table 6. After adjusting for age, BMI, symptom duration, and HH type, the Toupet procedure remained a statistically significant independent predictor of earlier postoperative oral intake (B = –0.273, 95% CI: –0.492~–0.054, $p = 0.015$) and shorter hospital stays (B = –0.694, 95% CI: –1.263~–0.126, $p = 0.017$) compared with the Nissen procedure. Furthermore, patients in the Toupet group had a significantly lower adjusted odds for experiencing any complication within one year postoperatively (OR = 0.327, 95% CI: 0.127~0.841, $p = 0.020$).

Discussion

This study assessed the clinical efficacy of 3D laparoscopic HH repair combined with either Toupet or Nissen fundoplication and revealed that both techniques are effective in managing GERD, demonstrating significant improvement in objective metrics and patient-reported symptoms. However, distinct differences were found between the two approaches regarding postoperative recovery, functional outcomes, and complication profiles, reflecting intrinsic mechanisms that provide critical evidence for supporting individualized surgical decision-making.

First, regarding early postoperative recovery, our study demonstrated significant advantages in the Toupet group, including shorter hospital stays and earlier time to first oral intake compared with the Nissen group, despite comparable operative duration and intraoperative blood loss. Notably, these findings were supported by our multivariate regression analysis, suggesting that the Toupet procedure facilitates faster recovery while maintaining procedural efficiency, potentially due to its lesser disruption of normal gastrointestinal physiological function.

Table 5. Comparisons of postoperative complications between the two groups [n (%)].

Group	Toupet group (n = 53)	Nissen group (n = 50)	χ^2-value	p-value
Acid reflux	3 (5.66)	1 (2.00)	Fisher	0.618
Heartburn	4 (7.55)	3 (6.00)	Fisher	1.000
Dysphagia	2 (3.77)	9 (18.00)	5.459	0.019
Abdominal distension/inability to belch	1 (1.89)	6 (12.00)	Fisher	0.055
Total	10 (18.87)	19 (38.00)	4.656	0.031

Table 6. Multivariable regression analyses of postoperative outcomes.

Outcome variable	Model type	B/OR	95% CI	p-value
Time to first postoperative oral intake (day)	Linear regression	–0.273	–0.492—0.054	0.015
Postoperative hospital stays (day)	Linear regression	–0.694	–1.263—0.126	0.017
Any complication	Logistic regression	0.327	0.127~0.841	0.020

B, unstandardized regression coefficient; OR, odds ratio.

At 6 months postoperatively, objective metrics unveiled intrinsic differences in the anti-reflux mechanisms of the two procedures. As demonstrated, the 360° circumferential wrap of the Nissen procedure established a robust mechanical barrier to reflux, evidenced by significantly higher postoperative LES resting pressure and more favorable 24-hour pH monitoring outcomes (reduced acid exposure time, fewer reflux episodes, and lower DeMeester scores). These findings corroborate that the Nissen technique creates a "high-pressure valve" effect, offering superior mechanical control of acid reflux [16]. In this cohort, the mean DeMeester score in the Nissen group dropped to levels well below the pathological threshold (<14.7), demonstrating near-complete normalization of acid reflux. However, this increased anti-reflux effect was accompanied by a higher incidence of dysphagia, consistent with previous meta-analyses [5,17]. This adverse event is likely due to excessive restriction of physiological distensibility at the gastroesophageal junction caused by the full-circle wrap, which can halt solid food transit, particularly in patients with preexisting esophageal motility dysfunction [18].

Conversely, the Toupet procedure represents a more physiological, balanced "moderate anti-reflux" modality. The 270° posterior partial wrap adequately elevates the LES baseline pressure and restores the cardia's flap-valve mechanism while preserving the anterior esophageal wall and facilitating physiological relaxation during swallowing and postprandial accommodation [18]. In this study, LES pressures in the Toupet group were normalized to physiological limits, and the mean DeMeester score improved significantly from preoperative 43.13 ± 8.16 to 10.64 ± 2.79 postoperatively. Although these values were numerically higher than those in the Nissen group, they remained substantially lower than preoperative levels and within or close to the normal range. This mechanism explains the lower dysphagia rates and reduced ineffective swallowing ratio observed in the Toupet group, indicating minimal interference with native esophageal peristalsis. Consequently, the Toupet approach appears particularly preferable for patients with preoperative esophageal motility disorders, such as ineffective esophageal motility [6].

A clinically pivotal finding from this study is that, despite the Nissen group providing superior control of objective reflux metrics, both groups achieved statistically comparable and clinically equivalent improvements in quality of life (QoL) at 1-year follow-up, as reflected by GERD-Q and GERD-HRQL scores. In both groups, the GERD-HRQL score decreased by more than 10 points from baseline, and the final scores were below the generally accepted "normal" threshold of 10 points [19]. These observations align with longitudinal QoL data demonstrating no significant differences in GERD-HRQL outcomes between the two groups at 1, 3, and 5 years postoperatively [20]. Collectively, these results suggest that the "moderate" but sufficient anti-reflux effect of the Toupet procedure is adequate to alleviate symptoms for most patients, yielding comparable QoL enhancements to the Nissen technique. From a patient-centered perspective, achieving satisfactory reflux control without inducing functional compromise appears more crucial than increasing physiological suppression at the cost of higher dysphagia and severe complications. The lower overall complication rates and reduced incidence of dysphagia observed in the Toupet group, coupled with multivariable analyses demonstrating the Toupet procedure as an independent protective factor for postoperative complications, support its suitability in appropriately selected patients. After controlling potential confounding factors, including age, BMI, duration of symptoms, and type of HH, the Toupet procedure remained an independent protective factor for the overall postoperative complications. Supporting this, a recent meta-analysis confirmed that Toupet achieves comparable reflux symptom control and QoL improvement compared to Nissen, with fewer postoperative adverse events [5].

These findings strongly advocate individualized surgical decision-making. In patients with preserved esophageal body peristalsis and a low ineffective swallowing ratio, the Nissen procedure offers the most robust anti-reflux protec-

tion and may be preferred. Conversely, for patients with preexisting or borderline esophageal motility, advanced age, or increased risk or concerns regarding postoperative dysphagia, the Toupet procedure represents a balanced, safer alternative. It provides effective reflux control while minimizing the risk of functional obstruction, thereby optimizing therapeutic efficacy and QoL.

Beyond 3D laparoscopy, robotic-assisted surgery is gaining traction in foregut procedures. The robotic platform provides enhanced dexterity and ergonomics, which may facilitate precise hiatal dissection and suture. However, current evidence does not demonstrate its long-term clinical superiority over laparoscopy, and its associated cost remains substantially higher [21,22]. Our findings indicate that 3D laparoscopy effectively overcomes the key limitation of 2D vision—impaired depth perception—at a fraction of the cost of robotics, positioning it as a highly balanced approach in terms of technical capability and cost-effectiveness. Prospective comparative studies directly assessing 3D laparoscopic and robotic techniques are needed to guide evidence-based selection of optimal surgical technology.

Despite compelling outcomes, we acknowledge several limitations associated with this study. First, it is a single-center, retrospective analysis, which is inherently susceptible to selection bias. Second, the relatively small sample size (n = 103) limits the statistical power to detect smaller but clinically significant differences between the groups and to accurately quantify the risk of rare complications. Third, the current postoperative follow-up duration of 1 year is insufficient to evaluate long-term symptom relapse and differences in anatomical recurrence between the two surgical techniques. Therefore, future multicenter, large-scale, prospective randomized controlled trials with extended follow-up are warranted to validate these findings.

Conclusions

The 3D laparoscopy provides evidence-based guidance for surgical decision-making in GERD patients with HH. Our findings delineate two distinct but effective therapeutic profiles. Nissen fundoplication creates a robust mechanical anti-reflux barrier and remains the physiologically superior choice for maximizing objective reflux control. In contrast, Toupet fundoplication establishes a compelling clinical advantage by facilitating a faster postoperative recovery and a significantly lower risk of troublesome dysphagia, without compromising the ultimate goal of patient satisfaction and quality-of-life improvement.

The most pivotal finding—that equivalent, excellent quality-of-life outcomes were achieved despite differences in objective metrics—challenges the sole pursuit of physiological perfection and underscores the importance of avoiding iatrogenic morbidity. We therefore propose a refined, patient-centric treatment algorithm: preoperative high-resolution manometry should be mandatory. For patients with preserved esophageal motility, the Nissen procedure remains an excellent option. However, for patients with impaired or borderline motility, or in whom a low risk of dysphagia is a priority, the Toupet technique should be strongly recommended as the first-line intervention. Utilizing 3D visualization to implement this tailored strategy enhances anatomic precision and optimizes both functional outcomes and the overall patient experience.

Availability of Data and Materials

The data analyzed are available from the corresponding author upon reasonable request.

Author Contributions

TEZ and DJG designed the research study and wrote the first draft. TEZ and DJG performed the research. TEZ and DJG analyzed the data. Both authors have been involved in revising it critically for important intellectual content. Both authors gave final approval of the version to be published. Both authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

The study obtained ethical approval from the Institutional Ethics Review Board of Jinhua Municipal Central Hospital (No.2025-284) and strictly adhered to the principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participating patients before enrollment.

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Conflict of Interest

The authors declare no conflict of interest.

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