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ABSTRACT
of the dissertation submitted for the degree of Doctor of Philosophy (PhD)

"Improving the Bariatric Efficacy of Gastric Bypass Using the FundoRing Method in Obesity"

Educational programme: 8D10100 “Medicine”
Executor: Duysenov Galymjan

Scientific consultant:
Dr. Med. Sci., Professor
Ospanov Oral
Foreign scientific consultant:
MD, PhD, MSc
Almantas Maleckas

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Relevance of the study

Obesity is one of the major contemporary public health challenges and ranks fifth among the leading causes of death worldwide [1]. In 2025, one in six residents of the European Union was living with obesity [2]. According to the National Center for Public Health of the Ministry of Healthcare of the Republic of Kazakhstan, more than 22% of the population of Kazakhstan suffers from obesity [3].

The global burden of obesity and diseases associated with a high body mass index (BMI) continues to increase, making sustainable obesity treatment not only a clinical challenge but also an important issue for decision-making at the organizational and economic policy levels of national healthcare systems [4].

Metabolic and bariatric surgery (MBS) is the most effective treatment for obesity, with proven safety in both the short and long term [5]. Despite advances in pharmacotherapy, conservative treatment methods, including medication, remain significantly less effective than surgical interventions [6].

Among bypass procedures, one-anastomosis gastric bypass (OAGB) is gaining a leading position and is increasingly competing with Roux-en-Y gastric bypass (RYGB) [7]. The popularity of OAGB can be attributed to its relative technical simplicity, pronounced metabolic effects, and shorter operative time compared with the alternative procedure, RYGB [8, 9]. Despite its advantages, OAGB does not eliminate the risk of adverse consequences arising from disturbances in the anatomical and functional relationships of the gastrointestinal tract following bariatric surgery. These may include biliary reflux, marginal (peptic) ulcers, dumping syndrome, early food intolerance, and nutritional deficiencies associated with malabsorption [10–17].

The main indications for revisional surgery after OAGB include not only biliary reflux esophagitis but also recurrent weight gain with the return of obesity due to dilation of the gastric pouch [18].

Rationale for the Present Study

The contemporary specialized literature on the subject of this dissertation contains data on the short- and long-term outcomes of OAGB, including assessments of quality of life using the Bariatric Analysis and Reporting Outcome System (BAROS) [19, 20]. OAGB has also been studied in comparison with other commonly performed procedures, such as sleeve gastrectomy (SG) and conventional Roux-en-Y gastric bypass [21].

The FundoRing method was developed by Professor O. B. Ospanov, a Kazakhstani researcher [22]. The invention is protected by Patent No. 37044, issued by the National Institute of Intellectual Property, a state enterprise under the Committee on Intellectual Property Rights of the Ministry of Justice of the Republic of Kazakhstan (Appendix A).

This development represents a novel approach to performing OAGB, characterized by a 10-cm gastric pouch and the innovative use of the excluded portion of the stomach to create a “living” ring with dual calibration. The width of the fundoplication cuff is 7 cm, comprising a 5-cm circumferential component and a 2-cm partial component [23]. Of the circumferential component, 3 cm covers the abdominal portion of the esophagus, while 2 cm covers the upper part of the gastric pouch. An additional 2-cm partial cuff also covers the upper portion of the gastric pouch, which should therefore be covered by a fundoplication cuff over a total

length of 4 cm.

A research team led by O. B. Ospanov conducted the scientific project AR23490186 (IRN), entitled “Development and Implementation of Gastric Bypass Using the FundoRing Method for the Treatment of Patients with Metabolic Syndrome.” The project was funded through a grant from the Ministry of Science and Higher Education of the Republic of Kazakhstan for the period 2024–2026. Initially, the study protocol was developed in 2021 and published in 2022 [24]. Subsequently, theoretical calculations of the gastric pouch dimensions were performed, and these calculations were validated using laparoscopic measurements and multislice computed tomography (MSCT) [25]. This work provided the basis for establishing the technical parameters and selecting standardized gastric pouch dimensions [23].

Further studies investigated the blood supply to the original fundoplication cuff using fluorescence angiography [26]. Measurements were also performed, and the dimensions and other anatomical and functional parameters of the gastric pouch were evaluated by endoscopic ultrasonography [27]. In addition, the anti-dumping effect of the new technique was investigated [28].

An important component of the research conducted by O. B. Ospanov’s team was a comparison of the original FundoRing-OAGB surgical technique with its closest prototype, in which the Nissen fundoplication technique was used during OAGB. The outcomes of these two fundoplication groups were also compared with those of a third group of patients who underwent OAGB without any form of fundoplication. The results demonstrated a higher safety profile in the FundoRing-OAGB group [29]. These findings, in turn, provided a basis for investigating the feasibility of implementing the technique in a hospital-substitution care setting [30].

An analysis and evaluation of carbohydrate metabolism and blood lipid profile parameters following OAGB with modified fundoplication, compared with the standard surgical technique, also demonstrated the advantages of the new procedure in the prevention and treatment of dyslipidemia, prediabetes, and type 2 diabetes mellitus (T2DM) [31]. Preoperative and postoperative endoscopic assessments of patients in the FundoRing-OAGB group revealed evidence of a more effective antireflux barrier in the intervention group [32].

O. B. Ospanov’s research team proposed a classification and indications for the combined use of fundoplication in metabolic and bariatric surgery [33, 34]. These recommendations were based on an analysis and evaluation of three-year outcomes obtained from 24-hour pH-impedance monitoring in patients who underwent gastric bypass using the FundoRing method [35]. The recommendations were also supported by findings from contrast radiographic examinations, insulin level measurements, and oral glucose tolerance testing [36].

Nevertheless, several important issues remained unresolved. The long-term outcomes of the FundoRing method, assessed using the BAROS criteria, had not been evaluated in comparison with those of standard laparoscopic OAGB. Three-year postoperative rates of both biliary and non-biliary reflux esophagitis had not been investigated using the modern method of pH-impedance monitoring. Other long-term complications following laparoscopic OAGB using the FundoRing technique had also not been sufficiently studied.

Furthermore, the absence of a clinical and economic evaluation of FundoRing-OAGB using a cost-effectiveness analysis over the long-term follow-up

period has prevented a comprehensive assessment of this surgical technology and the formulation of evidence-based recommendations for its implementation across the national healthcare system.

All of the aforementioned unresolved issues constituted the principal rationale for undertaking the present dissertation research.

Aim of the study: To study the results and evaluate the possibility of improving the bariatric efficacy of gastric bypass in obesity using the FundoRing method.

Objectives of the study:

1. To compare long-term results according to the criteria of the BAROS system after the application of the FundoRing method in comparison with the standard method of laparoscopic one-anastomosis gastric bypass;
2. To study and evaluate the results of the frequency of postoperative biliary and non-biliary reflux esophagitis and other long-term complications after the application of laparoscopic one-anastomosis gastric bypass using the FundoRing method.
3. To conduct a clinical and economic evaluation of the FundoRing-OAGB method using the "cost-effectiveness" method.

Study object: The object of the study is adult patients with obesity who have undergone one-anastomosis gastric bypass (OAGB).

The subject of the study is the differences in clinical efficacy, quality of life, reflux and late complications, as well as direct medical costs between the modified FundoRing-OAGB technique and standard OAGB.

Scientific novelty of the study:

1. Based on the results of the study, laparoscopic gastric bypass using the FundoRing technique received approval for the use of the developed technology with reimbursement of costs under the Compulsory Social Health Insurance (CSHI) system nationwide. The approval was granted by a decision of the Joint Commission on the Quality of Medical Services (JCQMS) of the Ministry of Healthcare of the Republic of Kazakhstan (Minutes No. 258 dated August 12, 2026) (Appendix G).
2. Based on the research findings, a monograph was published to provide physicians, including surgeons, with practical guidance on the application of the principal results of the dissertation research described therein.
3. The research findings formed the basis of the National Recommendations for the Development of Metabolic and Bariatric Surgery in the Republic of Kazakhstan, adopted at the 3rd International KaSBariMeT-2026 Congress (Appendix D).
4. The main provisions of the dissertation have been incorporated into university curricula, including the certification course entitled “Bariatric and Metabolic Surgery,” approved by the Committee of the State Unitary Enterprise for Surgical Discipline Programs (Minutes No. 2 dated December 12, 2023).
5. The results of the dissertation research have been included in the final report of the scientific project registered under Individual Registration Number (IRN) AR23490186 (2024–2026), funded through a grant from the Ministry of Science and Higher Education of the Republic of Kazakhstan. Project title: “Development and Implementation of Gastric Bypass Using the FundoRing Method for the Treatment of Patients with Metabolic Syndrome.”

Research Statements Submitted for Defense

1. The use of gastric bypass according to the FundoRing technique (FundoRing-

OAGB) results in a statistically significantly higher overall quality-of-life score according to the Bariatric Analysis and Reporting Outcome System (BAROS): 5.59 ± 1.13 versus 4.57 ± 1.09, corresponding to an improvement from a “good” to a “very good” outcome according to BAROS criteria.

2. The FundoRing technique demonstrates superior bariatric efficacy compared with standard OAGB, as assessed by the percentage of excess weight loss (%EWL): 84.3 ± 12.1% versus 76.8 ± 14.3% (a difference of 7.5 percentage points; $p < 0.001$), and by the proportion of patients achieving a BMI below 30 kg/m²: 94.2% versus 86.7% (a difference of 7.5 percentage points; $p = 0.002$).

3. FundoRing-OAGB reduces the incidence of biliary reflux esophagitis to 0.2%, compared with 9.4% in the control group, representing a 47-fold reduction ($p < 0.001$). It also reduces the incidence of marginal (peptic) ulcers at the gastrojejunal anastomosis to 0.2%, compared with 3.4% in the standard OAGB group, representing a 17-fold reduction ($p < 0.001$).

4. Clinical and economic analysis demonstrated that FundoRing-OAGB is associated with lower mean direct medical costs per patient: USD 5,928.10 ± 864.00 versus USD 6,758.00 ± 1,459.20. The incremental cost-effectiveness ratio (ICER) was USD 11,065 per additional patient achieving the target BMI, indicating the economic dominance of FundoRing-OAGB.

Presentation and Dissemination of Research Findings (Conference Presentations)

1. On October 9, 2024, the results of the dissertation research were presented at the Interdisciplinary Conference dedicated to the “Astana–Almaty–Bishkek–Shymkent–Tashkent Bariatric Marathon (Turkestan-2024),” entitled “Modern Methods of Treating Type 2 Diabetes Mellitus,” held in Shymkent, Kazakhstan. Presentation title: “National Consensus of Kazakhstani Surgeons and Endocrinologists on Metabolic Surgery for Type 2 Diabetes Mellitus.”

2. On October 11, 2024, a presentation was delivered at the International Scientific and Practical Conference “Prospects for the Development of Bariatric and Metabolic Surgery in Uzbekistan,” held in Tashkent, Uzbekistan. Presentation title: “Our Experience with the Developed FundoRing Gastric Bypass Technique in a Hospital-Substitution Bariatric Surgery Setting.”

3. On October 25, 2025, an oral presentation was delivered at the “2nd International Summit Forum on Gastroesophageal Reflux Disease & Bariatric-Metabolic Surgery and China Foregut Surgery Conference” in Urumqi, China. Presentation title: “Surgical Technique and Main Results of FundoRing One-Anastomosis Gastric Bypass.”

4. On April 24, 2026, a presentation was delivered at the 3rd Conference on Bariatric Surgery of the Caspian Region Countries in Baku, Azerbaijan. Presentation title related to the research: “Three-Year Follow-Up of 500 Patients: FundoRing versus Standard One-Anastomosis Gastric Bypass—A Randomized Study.”

5. On July 3, 2026, a presentation was delivered at the 3rd Congress of the Kazakhstan Society of Bariatric and Metabolic Surgeons in Astana, Kazakhstan. Presentation title related to the research: “Comparison of Five-Year Outcomes Regarding the Probability of Weight Regain Following One-Anastomosis Gastric Bypass and the FundoRing Technique.”

6. From September 1 to 4, 2026, a presentation was delivered at the International

Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) Congress in Toronto, Canada. Presentation title: “Three-Year Metabolic Syndrome Outcomes Following FundoRing-OAGB.”

Author’s Personal Contribution

The doctoral candidate personally performed the following components of the dissertation research: planning, organization, and implementation of all stages of the clinical study; data collection and processing; implementation of a standardized technique combining gastric bypass and fundoplication in clinical practice; database development; and statistical analysis of the obtained results. The doctoral candidate participated as the first assistant in 478 surgical procedures.

Implementation of Research Findings in Clinical Practice

Based on the dissertation research, the doctoral candidate obtained the following Republic of Kazakhstan (RK) intellectual property copyright certificates as the sole author:

1. Copyright Certificate No. 78935, dated September 25, 2026, entitled “Three-Year Reflux Profile, Late Complications, and Nutritional Safety of FundoRing One-Anastomosis Gastric Bypass Compared with Standard One-Anastomosis Gastric Bypass.”
2. Copyright Certificate No. 78936, dated September 25, 2026, entitled “Clinical and Economic Analysis of FundoRing One-Anastomosis Gastric Bypass Compared with Standard One-Anastomosis Gastric Bypass: Costs, Achievement of Target BMI, and ICER Over Three Years.”

Publications on the dissertation topic.

1. Ospanov O, Shikora S, Yelembayev B, Rakhmetova V, Zhumankulov K, Rysbekov M, Ospanova S, **Duysenov G**. Three-Year Outcomes of Reflux Esophagitis and Late Complications After FundoRing Versus Standard One-Anastomosis Gastric Bypass: a Randomized Controlled Trial. Obes Surg. 2026 Aug;36(8):4075-4083. doi: 10.1007/s11695-026-08769-0. Epub 2026 Jun 30.
2. Oral Ospanov, **Galymjan Duysenov**, Venera Rakhmetova, Zhanbolat Dildabekov, Bakhtiyar Yelembayev 3-Three Year BAROS Score Outcomes for One anastomosis Gastric Bypass and FundoRing One anastomosis Gastric BypassJ CLIN MED KAZ, Volume 23, Issue 3, pp. 4-10. https://doi.org/10.23950/jcmk/18692
3. Ospanov, O., **Duysenov, G**., Yelembayev, B., Yeleuov, G., & Dildbekov, Z. (2026). Cost-effectiveness analysis of FundoRing versus standard one-anastomosis gastric bypass: up to 3-year results of a randomized controlled trial. Annals of Medicine & Surgery, 88(10), 6404–6412. https://doi.org/10.1097/MS9.0000000000005625

Study design, materials and methods of the study

The dissertation research was conducted within the framework of scientific project AP 23490186 of the Ministry of Science and Higher Education of the Republic of Kazakhstan. The study design was a single-center, parallel-group, prospective, randomized controlled clinical trial. Patient recruitment took place from January 2021 to December 2024. During the screening phase, 1,146 potential participants were assessed. After 146 patients had been excluded, 1,000 patients were randomized in a 1:1 ratio into two groups of 500 participants each.

The study was conducted in accordance with the principles of the Declaration of Helsinki and the Code of the Republic of Kazakhstan “On Public Health and the Healthcare System.” The study was internationally registered under ClinicalTrials.gov identifier NCT04834635. The study protocol, entitled “The

FundoRing OAGB Versus Non-wrapping (Non-banded) Standard Method of Laparoscopic One Anastomosis Gastric Bypass," was published on the ClinicalTrials.gov website. The study protocol was approved by the Local Bioethics Committee of the Astana Medical University Non-Profit Joint-Stock Company (Appendix Ж).

Inclusion and Exclusion Criteria

The principal inclusion criteria were age 18–60 years, BMI of 30–50 kg/m², the presence of metabolic syndrome or clinically (metabolically) significant obesity, failure of previous nonsurgical weight-loss interventions, and an acceptable operative risk classified as ASA I–II. Patients with stable comorbidities, including type 2 diabetes mellitus (T2DM), arterial hypertension, dyslipidemia, and non-alcoholic fatty liver disease (NAFLD), were eligible for inclusion in both comparison groups.

Patients were excluded if they had a BMI greater than 50 kg/m²; severe reflux esophagitis classified as grade C or D according to the Los Angeles classification; no history of previous bariatric surgery or surgery involving the upper gastrointestinal tract; a giant hiatal hernia exceeding 5 cm; previous fundoplication or hiatal hernia repair; malignant disease; pregnancy; or an inability or unwillingness to provide informed consent for surgery or comply with the proposed follow-up schedule.

Clinical Research Methods

Randomization procedures. The randomization sequence was generated by a statistician or through computer-generated block randomization using a block size of four. Allocation concealment was ensured using sequentially numbered, identical, opaque, sealed envelopes. The envelopes were opened by a nurse who was not involved in patient recruitment or outcome assessment. Following randomization, neither the patients nor the operating surgeon were blinded to the assigned intervention because of the nature of the surgical procedures. Therefore, the study was conducted as an open-label randomized trial.

Both procedures were performed laparoscopically. In the FundoRing-OAGB group, a long, narrow gastric pouch measuring 10 cm along the lesser curvature was created and calibrated using a 32-Fr bougie. Following mobilization of the gastric fundus, division of the short gastric vessels, and dissection of the gastrosplenic ligament, the mobilized fundus was passed behind the abdominal portion of the esophagus from left to right. A "living ring" up to 5 cm wide was created around the esophagus, with an additional extension onto the gastric pouch, and secured to the staple line. A gastrojejunal anastomosis was then constructed using a 200-cm biliopancreatic limb.

In the standard OAGB group, the conventional surgical technique was performed, creating a gastric pouch measuring 15–18 cm in length without fundoplication.

Thus, the interventions differed in two related technical components. Accordingly, the dissertation refers to a "comparison of combined surgical strategies" rather than the "isolated effect of fundoplication."

A standardized Enhanced Recovery After Surgery (ERAS) protocol was applied in both groups. Postoperatively, patients were prescribed a liquid diet, pantoprazole 40 mg daily for the first 2–6 months, and standard vitamin and mineral supplementation. Scheduled follow-up visits were conducted at 1, 3, 6, 12, 24, and

36 months after surgery. At each visit, body weight, BMI, the presence and treatment of comorbidities, symptoms, endoscopic and laboratory findings, nutritional status, and postoperative complications were documented.

Primary Clinical Endpoint

The primary clinical endpoint of the present study was the composite BAROS (Bariatric Analysis and Reporting Outcome System) score at 36 months after surgery.

BAROS is a composite assessment tool that provides a comprehensive evaluation of bariatric treatment outcomes across three core domains: percentage of excess weight loss (%EWL), changes in associated medical conditions (comorbidities), and quality of life measured using the Moorehead–Ardelt Quality of Life Questionnaire II.

Points for postoperative complications and repeat surgical interventions were subtracted from the total score, thereby accounting for the safety and durability of the achieved outcomes.

Secondary Clinical Endpoints

The secondary clinical endpoints included BMI, change in BMI (ΔBMI), percentage of excess weight loss (%EWL), percentage of total weight loss (%TWL), the proportion of patients achieving a BMI below 30 kg/m², lipid and carbohydrate metabolism parameters, remission rates for type 2 diabetes mellitus (T2DM), arterial hypertension, and dyslipidemia, changes in quality of life, nutritional status, and the incidence of postoperative complications.

Remission was defined as the achievement of normal values for the relevant laboratory or instrumental parameters without the use of disease-specific pharmacological treatment. The following thresholds were applied: glycated hemoglobin (HbA1c) below 6.0%, blood pressure below 130/85 mmHg, and low-density lipoprotein cholesterol (LDL-C) below 100 mg/dL.

Endoscopic Assessment and Reflux Evaluation

According to the study protocol, routine esophagogastroduodenoscopy (EGD) was scheduled at two follow-up time points: one year and three years after surgery. Additional endoscopic examinations were performed when clinically indicated, including in patients presenting with reflux, dyspepsia, or signs of gastrointestinal bleeding.

Biliary reflux esophagitis was verified through a comprehensive assessment combining clinical symptoms, endoscopic signs of biliary gastropathy, and the detection of episodes with pH values above 7 during 24-hour pH-impedance monitoring, which were considered a surrogate marker of bile reflux into the esophagus.

Acid reflux esophagitis was defined as the presence of grade A–B endoscopic changes according to the Los Angeles classification, together with documented acid exposure at pH values below 4.

Twenty-four-hour pH-impedance monitoring was performed in a subgroup of patients selected sequentially from the overall cohort, with consideration of age and sex, comprising 175 patients in each group. Proton pump inhibitors (PPIs) were discontinued seven days before the examination.

The following parameters were assessed: acid exposure time, the number of acid, weakly acidic, and alkaline reflux episodes, and the DeMeester score. Twenty-four-hour pH monitoring was performed using a US-manufactured Digitrapper 24-

hour pH monitoring system purchased through the grant project associated with the present study.

Clinical and Economic Analysis

The clinical and economic analysis was conducted from the healthcare provider perspective, which determined the inclusion of direct medical costs in the calculations.

The following cost categories were considered: the initial surgical procedure and associated hospitalization, scheduled outpatient visits, laboratory tests, esophagogastroduodenoscopy (EGD), pH-impedance monitoring, nutritional counseling, vitamin and mineral supplementation, and the treatment of postoperative complications.

All resource costs were adjusted to 2025 prices and converted from Kazakhstani tenge (KZT) into US dollars (USD) using an exchange rate of KZT 521.59 per USD 1.

Indirect costs, productivity losses, transportation expenses, and direct out-of-pocket patient costs were excluded from the analysis, consistent with the stated analytical perspective.

A cost-effectiveness analysis was performed. The effectiveness criterion was the proportion of patients achieving the target BMI of less than 30 kg/m² at the last available follow-up visit.

The incremental cost-effectiveness ratio (ICER) was calculated using the standard formula:

\[ICER=\frac{C_f-C_s}{E_f-E_s} \]

where \(C_f\) and \(C_s\) represent the mean costs in the two comparison groups, and \(E_f\) and \(E_s\) represent the proportions of patients achieving the target BMI.

A negative ICER, in the context of lower costs and greater effectiveness, was interpreted as economic dominance of the corresponding strategy.

Uncertainty in the results was assessed using 5,000 nonparametric bootstrap replications and a one-way sensitivity analysis. The sensitivity analysis varied the exchange rate, cost structure, discount rate, and alternative definitions of treatment success.

Quality-adjusted life years (QALYs) were not calculated in the present study because of the nature of the available data, the stated analytical perspective, and the selection of the proportion of patients achieving a target BMI below 30 kg/m², rather than QALYs, as the effectiveness criterion.

Statistical analysis The sample size was calculated a priori, before the start of patient enrollment, based on two key endpoints: the primary one — the total BAROS score at 3 years, and the secondary one — weight loss (%EWL) at 3 years. For each endpoint, a power analysis was applied to compare two independent means.

Calculation for the primary endpoint (total BAROS score)

Calculation parameters:

- test — two-sided Student's t-test for two independent samples;
- significance level (α) — 0.05;
- power (1 – β) — 95% (β = 0.05);
- minimum clinically important difference (Δ) — 0.5 BAROS points (threshold

recommended by validation studies of the scale as the minimum clinically significant difference);

• standard deviation (σ) — 1.10 points (based on pilot data and literature on BAROS after bariatric surgery).

Formula for calculation: $n = 2 \cdot (Z\alpha/2 + Z\beta)^2 \cdot \sigma^2 / \Delta^2$

Substitution of values: $n = 2 \cdot (1.96 + 1.645)^2 \cdot 1.10^2 / 0.5^2$

$n = 2 \cdot 12.99 \cdot 1.21 / 0.25 = 31.44 / 0.25 \approx 126$ patients per group

Thus, the minimum required sample size for the primary endpoint was 126 patients per group (252 total), which provides 95% power to detect a difference of 0.5 BAROS points at $\alpha = 0.05$.

Calculation for the secondary endpoint (%EWL — percentage of excess weight loss)

Calculation parameters:

• test — two-sided Student's t-test for two independent samples;

• significance level (α) — 0.05;

• power (1 – β) — 95% (β = 0.05);

• minimum clinically important difference (Δ) — 7.5 percentage points (difference in %EWL that is considered clinically significant after bariatric surgery);

• standard deviation (σ) — 12.1% (based on literature on %EWL after OAGB).

Formula for calculation: $n = 2 \cdot (Z\alpha/2 + Z\beta)^2 \cdot \sigma^2 / \Delta^2$

Substitution of values: $n = 2 \cdot (1.96 + 1.645)^2 \cdot 12.1^2 / 7.5^2$

$n = 2 \cdot 12.99 \cdot 146.41 / 56.25 = 3803.7 / 56.25 \approx 68$ patients per group

Thus, the minimum required sample size for the secondary endpoint (%EWL) was 68 patients per group (136 total), which provides 95% power to detect a difference of 7.5 percentage points at $\alpha = 0.05$.

Given the expected attrition over 3 years of follow-up (according to the literature — up to 15–20% after bariatric surgery), as well as the need for subgroup analysis (pH-impedance monitoring, 175 patients per group) and economic analysis (taking into account different time points), the final sample size was increased to 500 patients per group (n = 1000).

Quantitative variables were presented as mean and standard deviation; nonparametric tests were used for non-normal distribution. Between-group comparisons were performed using the t-test for independent samples or the Mann–Whitney U test; categorical variables were compared using χ^2 or Fisher's exact test. Within-group changes were assessed using the paired t-test. A two-sided $p < 0.05$ was considered statistically significant. For the main continuous and binary outcomes, differences and 95% confidence intervals (CI) were reported.

When interpreting the results, the lack of access to individual data, unequal denominators, loss to follow-up, absence of adjustment for multiple comparisons, and inconsistency of some p-values with the original means were taken into account. In this regard, numerical results are presented as published, indicating their analytical time point; missing indicators were not reconstructed.

Discussion

This dissertation integrates three complementary dimensions of bariatric effectiveness. The first is the patient-oriented BAROS assessment. The second is objective safety and reflux physiology. The third is healthcare system expenditure. This integrated approach makes it possible to evaluate not only weight reduction but also the ability of a surgical procedure to maintain functional and economic outcomes.

In the three-year complete-case analysis, FundoRing-OAGB achieved a higher BAROS score. The difference of 1.02 points reflected advantages in weight loss, obesity-related medical conditions, and quality of life. The clinical explanation is associated with simultaneous improvements in anthropometric outcomes and a reduction in symptomatic postoperative complications. The difference in %EWL was 7.5 percentage points, while the proportion of patients achieving a BMI below 30 kg/m² was also higher by 7.5 percentage points. These findings are consistent with the hypothesis that the shorter gastric pouch and the "living ring" reinforce the restrictive component of the procedure. However, gastric pouch length is an independent technical factor; therefore, the findings indicate an advantage of the overall FundoRing-OAGB strategy rather than an isolated effect of fundoplication.

Metabolic Effects and Disease Remission

Mean HbA1c, HOMA-IR, LDL-C, total cholesterol, and triglyceride levels were lower following FundoRing-OAGB. However, the analysis of binary remission outcomes for T2DM and hypertension did not reveal statistically significant differences between the groups. This distinction between continuous and binary endpoints is methodologically important: a change in the mean value of a laboratory parameter may be clinically beneficial but does not necessarily translate into a difference in the proportion of patients who have completely discontinued pharmacological treatment.

The high remission rates for T2DM and hypertension in both groups confirm the substantial metabolic potential of OAGB as an established bariatric procedure. Nevertheless, the prevention of obesity recurrence requires consideration of follow-up duration, weight regain, dietary quality, physical activity, medication use, and nutritional status. A three-year follow-up period allows the assessment of medium-term durability but does not exclude the possibility of subsequent weight regain. Therefore, longer-term follow-up is necessary in future studies.

Reflux Profile and Complications

The reduction in pH-impedance parameters and clinically significant biliary reflux represents one of the most notable advantages of FundoRing-OAGB. The "living ring," created from the mobilized gastric fundus, may provide an additional barrier against the reflux of hydrochloric acid and bile into the esophagus. This technique also permits the creation of a shorter gastric pouch, reducing its volume and potentially decreasing the risk of peptic ulceration. Furthermore, the fundoplication component extends not only around the esophagus but also over a 4-cm segment of the gastric pouch, potentially reducing the likelihood of subsequent pouch dilation.

Economic Implications of the Findings

The additional technical complexity of FundoRing-OAGB increased the cost of the

initial hospitalization by approximately USD 60.50. However, this difference was outweighed by the savings associated with complications, endoscopic surveillance, pharmacological treatment, and additional outpatient visits in the standard OAGB group.

As a result, the FundoRing-OAGB strategy demonstrated economic dominance according to two criteria: lower overall costs and a greater proportion of patients achieving the target BMI. This conclusion is relevant to healthcare systems because it indicates that preventing postoperative complications may have a greater impact on total expenditure than a modest increase in operative duration and direct surgical costs.

Conclusions

1. FundoRing-OAGB provides a statistically significantly higher overall BAROS score than standard OAGB: 5.59 ± 1.13 versus 4.57 ± 1.09 points, with a mean difference of 1.02 points (95% CI 0.87–1.17; $p < 0.001$). The advantage was observed across all three main BAROS components: weight loss (2.36 ± 0.64 versus 2.19 ± 0.60), improvement in obesity-related medical conditions (1.34 ± 0.67 versus 0.96 ± 0.69), and quality of life (1.87 ± 0.71 versus 1.41 ± 0.55; $p < 0.001$ for all comparisons). The FundoRing-OAGB group also demonstrated a higher %EWL ($84.3 \pm 12.1\%$ versus $76.8 \pm 14.3\%$) and a greater proportion of patients achieving a BMI below 30 kg/m² (94.2% versus 86.7%).

2. Three years after surgery, the incidence of clinically significant biliary reflux esophagitis, marginal ulcers, and dumping syndrome was lower following FundoRing-OAGB than following standard OAGB: 0.2% versus 9.4%, 0.2% versus 3.4%, and 13.7% versus 36.5%, respectively ($p < 0.001$). In the pH-impedance subgroup, comprising 175 patients per group, FundoRing-OAGB was associated with lower acid, weakly acidic, and alkaline reflux burdens and a lower DeMeester score (3.97 ± 1.8 versus 7.2 ± 7.4; $p < 0.001$). Early food intolerance was more frequent following FundoRing-OAGB, but this difference had disappeared by the third postoperative year. No significant differences were identified in protein-energy malnutrition, anemia, or thiamine deficiency. A pH value above 7 is an important diagnostic indicator, although it remains a surrogate marker of biliary exposure and does not replace direct chemical confirmation of the presence of bile.

3. FundoRing-OAGB achieved a greater proportion of patients with a BMI below 30 kg/m² (94.2% versus 86.7%) while incurring lower mean direct medical costs (USD 5,928.10 versus USD 6,758.00 per patient). The cost difference was −USD 829.90, representing a reduction of approximately 12.3%, while the ICER was −USD 11,065 per additional patient achieving the target BMI. All 5,000 bootstrap replications supported the direction of the effect, indicating lower costs and greater effectiveness. This conclusion applies to the healthcare system perspective, direct medical costs, and the selected follow-up period.

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