Research Square

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Comparative Weight Loss Trajectories After Revisional Metabolic Bariatric Surgery: Restrictive-to Hypoabsorptive vs. Hypoabsorptive-to-Modified Hypoabsorptive Approaches

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Abstract

Introduction: Revisional metabolic bariatric surgery (RMBS) is increasingly performed in patients with Suboptimal Clinical Response (SoCR) or recurrent weight gain (RWG) after primary bariatric procedures. Two principal approaches are used: converting a restrictive procedure into a hypoabsorptive one (RH), or modifying an existing hypoabsorptive procedure (HH). This study aimed to evaluate five-year weight-loss outcomes and determine predictors of long-term total weight loss percentage (TWL%) in patients in RH group versus HH group.

Methods: Data from 449 adults registered in the Iran National Obesity and Metabolic Surgery Database were analyzed. Patients were categorized based on revisional strategy. Demographic and clinical variables were collected from primary surgery through 60 months after revision. TWL% trends were assessed at predetermined time points. Multivariable regression identified predictors of pre-revisional BMI and TWL% at 18 and 24 months.

Results: The RH group had a higher pre-revisional BMI than the HH group (42.9 vs. 39.3 kg/m²). Both groups showed increased TWL% after revision, peaking at 18 months, with greater early and mid-term weight loss in the RH group. However, higher RWG in this group resulted in similar outcomes at 60 months. Younger age, longer interval between surgeries, higher initial BMI, and higher postoperative nadir predicted greater pre-revisional BMI. HH revision independently predicted lower TWL% at 18 and 24 months, whereas higher revision BMI predicted greater TWL%.

Conclusion: Revisional strategy significantly influences short- and mid-term outcomes, although long-term results converge. Baseline BMI and patient characteristics are important determinants of success, highlighting the need for individualized surgical planning.

Highlights

• Revisional metabolic bariatric surgery produced significant weight-loss improvements in both surgical pathways.

• Patients converted from restrictive to hypoabsorptive procedures achieved greater total weight loss over time.

• Pre-revisional BMI and early postoperative weight-loss trends were strong predictors of long-term outcomes.

• Modified hypoabsorptive-to-hypoabsorptive revisions offered durable metabolic benefits with acceptable risk.

Introduction

Obesity is a global health crisis whose prevalence has nearly tripled since 1975, now affecting over 650 million adults worldwide (1). MBS has emerged as the most effective long-term treatment for severe obesity, producing substantial and sustained weight loss while also improving or resolving obesity-associated medical problems (2). Despite the overall success of primary MBS procedures, a subset of patients experiences suboptimal clinical response (SoCR) or recurrent weight gain (RWG) after the initial surgery.

According to the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) consensus, a SoCR (Suboptimal Clinical Response) is defined as either insufficient weight loss typically operationalized as a total body weight (TWL) loss of less than 20% or an inadequate improvement in a clinically significant obesity- associated medical problem that constituted an indication for surgery. In contrast, RWG refers to a late postoperative deterioration characterized by a regain of more than 30% of the initial weight lost after surgery or the recurrence/worsening of obesity- associated medical problems following an initial satisfactory response (3).

Revisional metabolic bariatric surgery (RMBS) has consequently become an important second-line intervention for these patients, now accounting for approximately 17% of all MBS (4,5). Notably, RWG is the most common indication for RMBS, comprising about two-thirds of revisional cases (6). Revisional procedures can be broadly grouped by surgical strategy into two categories: converting a prior restrictive procedure to a hypoabsorptive procedure, also called Restrictive-to-Hypoabsorptive (RH), or modifying a previous hypoabsorptive procedure to a modified hypoabsorptive configuration, also called Hypoabsorptive-to-modified Hypoabsorptive (HH). In the first pathway – RH – a patient with an initial purely restrictive surgery (such as Sleeve Gastrectomy (SG) or Gastric Banding (GB)) is converted to a hypoabsorptive procedure like Roux-en-Y gastric bypass (RYGB), One-Anastomosis Gastric Bypass (OAGB), or biliopancreatic diversion/duodenal switch (BPD/DS). In the second pathway – hypoabsorptive-to-modified hypoabsorptive – a patient with a prior hypoabsorptive surgery undergoes revision to further increase the malabsorptive effect. Typical scenarios include lengthening the bypassed intestinal limb of an RYGB (distalization) or converting a standard RYGB to a more potent malabsorptive procedure (such as a DS or OAGB) to counteract RWG (7). These hypoabsorptive-to-modified hypoabsorptive revisions are selected when an initial bypass has achieved SoCR or RWG, based on the hypothesis that increasing nutrient malabsorption or restriction will lead to further weight loss for the patient. Despite the increasing frequency of RMBS, a notable gap remains in the literature regarding outcomes comparisons between these two revision pathways. Moreover, prior studies often report weight loss at single postoperative time points (for instance, one-year percent excess weight loss) rather than examining the trajectory of weight change over multiple years. Evaluating weight-loss trajectories is clinically meaningful because many patients experience some degree of RWG after the initial postoperative period (8). Therefore, understanding how different revisional strategies affect initial weight loss and the rate of weight regain (or weight loss maintenance) is crucial for informed clinical decision-making. To date, however, there is limited information on how weight-loss trajectories compare between the two main types of RMBS, underscoring the need for studies specifically examining the durability of weight loss after different revision approaches.

In this context, our study aims to compare weight-loss outcomes, particularly the long-term weight-loss trajectories, between patients undergoing RH revisional surgery and those undergoing HH revisional surgery. We longitudinally assessed weight loss and weight maintenance trajectories in both groups to determine which revision strategy offers superior and more durable results based on each patient's personal characteristics.

Methods

Participants and Inclusion Criteria

The study population was derived from the Iran National Obesity and Metabolic Surgery Database (INOSD) (9). We identified all adult individuals aged 18 years or older registered in INOSD who underwent revisional MBS between 2012 and 2022 Revisional MBS was defined as the first or second bariatric reoperation performed after a primary MBS, conducted to address SoCR or RWG. Patients whose initial revision was performed primarily for complication management such as leaks, strictures, ulcers, or band-related complications were not considered eligible for inclusion. Individuals with emergency procedures, a history of unrelated major upper gastrointestinal surgery, or substantial missing data for key variables were excluded.

Study Setting

All revisional procedures were performed by faculties of a fellowship training center, endorsed by the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO). Surgeries were performed at a tertiary high-volume MBS center which is center of excellence for MBS in Tehran, Iran, each operating under standardized clinical protocols and contributing data uniformly to the INOSD registry.

Patients were stratified into two groups based on the nature of their primary procedure and the revisional operation they received. The first group consisted of individuals whose primary operation had been a restrictive procedure, such as SG, LAGB, Gastric plication (GP), or VBG, and who underwent conversion to a hypoabsorptive procedure during their revision. The second group comprised patients whose primary procedure had included a hypoabsorptive or mixed mechanism such as RYGB, OAGB, duodenal switch (DS), Jejunoileal bypass (JIB), or other bypass-based procedures and who underwent a modified hypoabsorptive revision aimed at enhancing or extending the malabsorptive component. These revisions typically included distalization or conversion of a prior bypass.

All revisional surgeries were performed laparoscopically under general anesthesia. Standard surgical steps included careful adhesiolysis, restoration of normal anatomy when necessary, and reconstruction of the gastrointestinal pathway according to the chosen technique. For RH conversions, a new gastric pouch or calibrated sleeve was fashioned using serial firings of linear staplers, typically over a 36 Fr bougie or sizing tube. Gastrojejunal or gastroileal anastomoses were created using linear staplers and

reinforced with absorbable running sutures. Limb lengths were selected according to institutional guidelines, with alimentary limbs (AL) generally measuring 75 cm and biliopancreatic limbs (BPL) measuring one third of whole small bowel considering common channel of 4 meter for HH and for RH we consider 200 cm of BPL, although minor adjustments were made when appropriate. For HH procedures, surgeons performed revision of the existing bypass, remeasurement of intestinal limb lengths using atraumatic graspers and calibrated marked tapes, and modification of the common channel to a standardized length around 400 cm.

Postoperative care followed a uniform pathway across all centers. Patients were mobilized on the day of surgery and received thromboprophylaxis, proton pump inhibitors, antiemetic prophylaxis, and hydration in accordance with enhanced recovery protocols. A clear liquid diet was initiated within the first 24 hours and advanced gradually to pureed and soft diets over the ensuing weeks. All patients received routine postoperative supplementation with multivitamins, calcium, vitamin D, vitamin B12, iron, and other micronutrients in accordance with IFSO recommendations. Scheduled follow-up visits occurred at approximately 10 days; 1, 3, 6, 9, 12, 18, 24, 36, 48, and 60 months after revisional surgery. At each visit, patients underwent weight measurement, evaluation of nutritional status, assessment of comorbidities, and reinforcement of dietary and lifestyle guidance. Data from these visits were recorded directly into the INOSD registry.

Data Collection and Variables

Data regarding baseline demographic and socioeconomic variables, including age, sex, marital status, educational attainment, employment status, and smoking history, were collected retrospectively. Clinical variables, including the past medical history and concurrent medication use, were also documented.

Anthropometric variables were recorded at four key time points: BMI before the primary surgery (BMI1), nadir BMI following the primary surgery (BMI2), BMI immediately before revisional surgery (BMI3), and nadir BMI after revisional surgery (BMI4). The interval between the primary and revisional surgeries was measured in years. Additional derived variables included the change between post-revision nadir and post-primary nadir (BMI4 − BMI2) and the overall change in BMI from the pre-primary baseline to the post-revision nadir (BMI4 − BMI1). A “successful catch of the previous nadir BMI” was defined as achieving a BMI after the revisional surgery that was equal to or lower than the minimum BMI attained after the primary surgery.

The primary longitudinal variable of interest was total weight loss percentage (TWL%) after revisional surgery. TWL% was assessed at all scheduled postoperative time points from 10 days through 60 months. Measurements falling within predefined visit windows were accepted as valid. When multiple eligible measurements existed for a given interval, the value closest to the target date was used. All outcome variables, including TWL%, BMI trajectories, and achievement of prior nadir, were included in the analysis.

Statistical Analysis

Continuous variables were summarized as means with standard deviations (SDs), and categorical variables as frequencies with percentages. Missing data were handled using multiple imputation by chained equations (MICE) with 50 rounds of imputation to minimize bias and retain statistical power.

Group comparisons of total weight loss (TWL%) at different follow-up time points were conducted using the Mann–Whitney U test or the independent samples t-test, depending on the distributional assumptions assessed by Shapiro–Wilk tests. Longitudinal changes in BMI and weight loss trajectories were visualized using line plots that displayed mean values and standard deviations.

Additionally, linear regression models were fitted by pooling results from 50 rounds of imputation using the MICE algorithm to explore predictors of pre-revisional BMI and TWL at 18 and 24 months following revisional surgery. A two-sided p-value < 0.05 was considered statistically significant throughout.

All analyses were performed using R version 4.5 (R Foundation for Statistical Computing, Vienna, Austria).

Ethical Considerations

The study was reviewed and approved by the Institutional Review Board (IRB) of Iran University of Medical Sciences (Approval No. [BLINDED]). All procedures were performed in accordance with the ethical standards outlined in the Declaration of Helsinki. Given the retrospective nature of the study and the use of anonymized data from the INOSD registry, the requirement for informed consent was waived.

Results

General Characteristics of the Participants

A total of 449 participants were included, comprising 300 in the RH group and 149 in the HH group. Of the included participants, 372 (82.9%) were female, and 77 (17.1%) were male, with a mean age of 41.5 ± 10.9 years. The most common primary bariatric procedures were sleeve gastrectomy (SG, 43.4%), one-anastomosis gastric bypass (OAGB, 15.1%), laparoscopic adjustable gastric banding (LAGB, 13.6%), and Roux-en-Y gastric bypass (RYGB, 12.7%). Revisional operations most frequently consisted of OAGB (53.2%) and RYGB (28.9%), with smaller numbers undergoing other procedures.

At the time of revisional surgery, the mean BMI of the cohort was 42.9 ± 7.1 kg/m² in the RH group and 39.3 ± 9.4 kg/m² in the HH group. The mean interval between the primary and revisional operation was 6.9 ± 3.8 years. Prior to the index bariatric procedure, patients had a mean BMI of 50.0 ± 24.3 kg/m², which decreased to a nadir of 33.4 ± 24.4 kg/m² following the first surgery. Following revision, total weight loss (TWL%) increased progressively over time. At 18 months, the mean TWL reached its highest level (23.2%), representing the peak of postoperative weight reduction. Thereafter, TWL values declined

modestly, measuring ≈22.6% at 24 months and ≈19.4% at 60 months, consistent with partial weight regain in the long term. Baseline demographics, pre-operative characteristics, and post-operative outcomes of the participants are summarized in Table 1.

Table 1- General Characteristics, Past Medical History, and Drug History of the Study Participants

Outcomes Between Groups

At the time of revisional surgery, the mean pre-operative BMI was higher in the RH group compared with the HH group (42.90 ± 7.07 vs. 39.30 ± 9.40). Following surgery, the TWL% increased progressively in both groups, reaching its maximum at 18 months (HH: 15.25 ± 17.72 vs. RH: 26.71 ± 11.41), after which the values gradually declined. Baseline Weight-Related Characteristics of the Study Participants are outlined in Table 2.

Table 2- Baseline Weight-Related Characteristics of the Study Participants

At key follow-up points, the RH group demonstrated significantly greater TWL% compared with the HH group. By 60 months, TWL% had decreased in both groups, consistent with partial long-term weight regain, and the difference between groups was no longer statistically significant.

A comprehensive comparison of TWL% between groups across all time points is outlined in Table 3 and Figure 1.

Table 3- Total Weight Loss (TWL%) Comparison Between Groups

Predictors of pre-Revisional BMI

To identify factors associated with BMI at the time of revisional surgery, we fitted a multivariable linear regression model. Based on the obtained results, younger age, a longer interval between the primary and revisional procedures, higher BMI before the first surgery, and higher nadir BMI after the first surgery were each independently associated with a higher BMI before the revisional surgery. In addition, patients in the HH group had a significantly lower pre-revisional BMI compared with those in the RH group, indicating that the revision pathway itself was an important determinant of BMI at the time of re-operation. In contrast, sex, smoking status, past medical history, and all recorded medications (including aspirin, statins, antihypertensives, metformin, and proton-pump inhibitors) were not independently associated with pre-revisional BMI after adjustment for the above weight-related variables. Details of the multivariate linear regression models predicting pre-revisional BMI are outlined in Table 4.

Table 4- Predictors of BMI Before Revisional Surgery

Predictors of the Long-Term Weight Loss Outcomes After Revisional Surgery

To further explore determinants of sustained weight loss after revisional bariatric surgery, we fitted multivariable linear regression models to predict TWL% at 18 months and 24 months.

At 18 months, belonging to the Hypoabsorptive-to-Modified Hypoabsorptive group was independently associated with lower TWL% ($\beta = -5.07$, $p = 0.026$), while a higher baseline BMI prior to revision predicted greater TWL% ($\beta = 1.24$, $p < 0.001$). Conversely, a higher BMI prior to the primary surgery was associated with lower TWL% ($\beta = -0.52$, $p = 0.027$).

At 24 months, similar predictors were observed. The group affiliation remained significant, with the Hypoabsorptive-to-Modified Hypoabsorptive pathway predicting lower TWL%. ($\beta = -4.31$, $p = 0.048$). A higher baseline BMI at revision was again positively associated with a greater TWL% ($\beta = 1.26$, $p < 0.001$), whereas a higher BMI prior to the primary operation predicted a lower TWL% ($\beta = -0.50$, $p = 0.016$).

Across both models, demographic variables (age, sex, smoking status), clinical comorbidities (e.g., diabetes, dyslipidemia, hypothyroidism, hypertension), and drug history were not significant independent predictors. Details of the multivariate linear regression models predicting weight loss outcomes in 18 months and 24 months after the revisional surgery are outlined in Table 5.

Table 5- Multivariate linear regression models to predict TWL after 18 and 24 months post-revisional surgery

Discussion

Revisional MBS remains a relevant option as more patients experience RWG or SoCR following their initial operation. In this study, we compared two of the most commonly encountered revisional pathways: conversion from a restrictive to a hypoabsorptive procedure and modification of a previous hypoabsorptive operation to understand how these strategies shape long-term weight-loss trajectories. The analysis revealed that patients who underwent an RH revision lost weight more rapidly and achieved a higher peak of total weight loss in the first few years after revision. Patients who moved from one hypoabsorptive procedure to a modified hypoabsorptive procedure had a slower, more modest increase in weight loss over time. However, the RH group also experiences more RWG after reaching its peak. Due to greater amounts of RWG, TWL in both groups gradually converged by the 60-month follow-up, and their ability to recapture or surpass their nadir BMI remained similar.

These patterns align with previous long-term studies. Ribeiro et al. reported that at 10 years, 56.7% of patients who underwent RMBS experienced SoCR or RWG and that SG patients regained significantly more weight than RYGB patients (10). Similarly, Tan et al. observed that although early %TWL after SG and bypass procedures was comparable, bypass procedures maintained superior weight loss at 5 and 10 years, while SG was associated with higher significant weight regain at both time points (11).

Evidence from revisional cohorts supports the same theme. Petriuk et al. demonstrated that conversion from SG to RYGB initially resulted in substantial additional weight loss. Still, this effect diminished over time, with %TWL decreasing from 40.2% at nadir to 33.3% at approximately 6.6 years (12). This progressive attenuation mirrors the RWG trajectory we observed, particularly within the RH pathway, and highlights that even with a more potent anatomical revision, long-term weight stabilization remains challenging.

Taken together, these external findings are consistent with our observation that, despite initial differences, particularly greater early and mid-term loss in RH, both revisional pathways ultimately show partial weight recovery and converge in long-term outcomes.

Understanding the differences in weight-loss trajectories between the two revision methods requires examining both baseline characteristics and weight-related patterns before the revisional operation. Patients whose primary operation was restrictive showed higher rates of dyslipidemia and greater atorvastatin use at the time of revision. This pattern is expected because restrictive procedures do not meaningfully alter the hormonal and metabolic pathways involved in lipid handling, insulin sensitivity, and bile-acid signaling (13,14). In contrast, hypoabsorptive operations typically provide stronger and more durable metabolic benefits, which help prevent or improve metabolic-syndrome–related comorbidities even in the presence of some degree of RWG (15,16). Another important consideration is the physiological response after distalization procedures in the HH group. Over time, adaptive changes and increased tolerance within the gastrointestinal tract may influence postoperative weight trajectories. In this context, distalization may promote additional weight loss through increased malabsorption and progressive adaptation of the alimentary pathway that affects nutrient handling and energy balance. This mechanism may partly explain the sustained weight reduction observed after HH revisions in the longer term. For this reason, patients whose first surgery was hypoabsorptive were less likely to present with dyslipidemia or to require lipid-lowering therapy at the time of revision. Both groups also showed almost identical nadir BMIs after the first surgery. This similarity suggests that the initial physiological response to bariatric surgery was comparable between groups, and that the type of the first operation did not strongly influence the lowest weight attained. However, pre-revisional BMI differed clearly between the two pathways. Patients who initially underwent restrictive surgery reached revision with a significantly higher BMI. This pattern aligns with previous observations showing that patients who undergo restrictive procedures are more prone to long-term RWG than those who undergo hypoabsorptive operations (17).

Our additional regression analysis provided further insight into the determinants of BMI at the time of revision. Younger patients, those who had a longer interval between operations, those who entered

primary surgery with a higher BMI, and those who achieved a higher nadir after the first operation were all more likely to present with a higher BMI before revision, regardless of their initial surgical type. These associations are consistent with previous studies showing that higher preoperative BMI and younger age are two of the strongest predictors of subsequent weight regain (18,19).

Predictors of long-term weight loss after revisional surgery also showed a similar emphasis on baseline BMI characteristics and surgical pathway, confirming that these elements play a central role in shaping postoperative trajectories at 18 and 24 months. The regression models identified several predictors that independently shaped weight loss at 18 and 24 months after revisional surgery. Belonging to the HH group was consistently associated with lower total weight loss, indicating that these patients lost roughly 4–5% less weight than those in the RH group. BMI before the first surgery also carried a negative association with long-term weight loss, suggesting that patients who initially had higher BMI values were less responsive to revision. In contrast, BMI before the revisional surgery showed a positive effect on postoperative weight loss, meaning that patients presenting with higher BMI at the time of revision experienced greater relative weight reduction.

These findings offer several practical considerations for selecting the optimal primary MBS procedure. When evaluating a patient for surgery, it is crucial for the clinician to anticipate the expected course of weight loss after the initial operation and the possibility that the patient may require revision in the future. Our results suggest that patients who undergo a restrictive procedure as their first operation are more vulnerable to significant long-term regain and often reach revision with a higher BMI, meaning they will depend more heavily on the weight-loss potential of their revisional surgery. Because restrictive procedures create neither durable hormonal effects nor sustained malabsorptive changes, they may not be the ideal first-line choice for individuals who already show characteristics associated with a higher risk of future RWG or SoCR to revision. Younger patients and those with a high baseline BMI fall into this category based on our results and other observational studies (20). Specifically, in individuals with a markedly elevated BMI, surgical planning may benefit from a staged strategy in selected cases. When the likelihood of needing future revision is anticipated, an initially restrictive procedure may be preferable, because it preserves the option of subsequent conversion to a more malabsorptive procedure if RWG or SoCR occurs. In contrast, selecting a bypass procedure as the initial operation may limit the flexibility of future revisional choices. Therefore, in patients with very high BMI, the choice of the primary operation should be based on a two-staged strategy considering the expected short-term weight loss and the probability of future revisional needs.

This study has several limitations that should be considered when interpreting the findings. Its retrospective design introduces the possibility of selection bias, particularly in how patients were allocated to different revisional pathways. Although the completeness and accuracy of certain variables such as lifestyle factors, dietary adherence, and behavioral contributors to weight regain could not be fully verified. Surgical details, including limb lengths and technical variations, were not specifically reported nor considered as predictors in regression models. Long-term follow-up data were incomplete for some patients, necessitating multiple imputation, which cannot fully replace observed

measurements. Additionally, the study did not assess nutritional deficiencies, quality of life, or remission of comorbidities, which are relevant outcomes in revisional surgery. These limitations highlight the need for prospective, standardized studies to validate and expand upon our findings.

Conclusion

In summary, our study demonstrates that the revisional pathway plays a central role in shaping both early and long-term weight-loss outcomes after bariatric surgery. Converting a restrictive procedure to a hypoabsorptive one produces stronger mid-term results than converting a hypoabsorptive approach to a modified hypoabsorptive approach. At the same time, long-term trajectories tend to converge across approaches. Baseline BMI patterns and patient characteristics further influence these outcomes. Recognizing these factors can help clinicians choose more durable primary operations and optimize future revisional strategies.

Declarations

Conflict of Interests Statement

The authors declare that they have no conflict of interest.

Data Availability Statement

All the data supporting the results of this original research are available upon request from the corresponding author of this study.

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Tables

Table 1- General Characteristics, Past Medical History, and Drug History of the Study Participants

Variable	RH group (n=300)	HH group (n=149)	p-value
Demographic characteristics			
Male Gender – n (%)	50 (65%)	27 (35%)	0.700
Age	41.53 ± 10.86 (Years)		
First surgery type – n (%)	SG: 195 (65%) LAGB: 60 (20%) LPG: 23 (8%) VBG: 19 (6%) GP: 3 (1%)	OAGB: 68 (46%) RYGB: 57 (38%) JIB: 10 (7%) Other bypass-based operations: 14 (9%)	N/A
Marriage status – n (%)	Married: 202 (68%) Single: 72 (24%) Divorced: 15 (5%) Widow: 10 (3%)	Married: 108 (72%) Single: 34 (23%) Divorced: 6 (4%) Widow: 1 (1%)	0.318
Job – n (%)	Housekeeper: 127 (43%) Employee: 74 (25%) Self-employed: 52 (18%) Student: 15 (5%) Unemployed: 12 (4%) Retired: 9 (3%) Others: 11 (2%)	Housekeeper: 69 (46%) Employee: 39 (26%) Self-employed: 28 (19%) Student: 3 (2%) Unemployed: 6 (4%) Retired: 1 (1%) Others: 3 (2%)	0.435
Education level – n (%)	High School Diploma: 106 (36%) Graduate: 85 (28%) Master's Degree: 45 (15%) Secondary Education: 26 (8%) Doctorate: 12 (4%) Undergraduate: 14 (5%) Primary Education: 9 (3%) Uneducated: 2 (1%)	High School Diploma: 61 (41%) Graduate: 25 (17%) Master's Degree: 17 (11%) Secondary Education: 20 (13%) Doctorate: 10 (7%) Undergraduate: 8 (5%) Primary Education: 7 (5%) Uneducated: 1 (1%)	0.108

Past Medical History			
Type 2 Diabetes Mellitus – n (%)	32 (11%)	8 (5%)	0.064
Dyslipidemia	72 (24%)	9 (6%)	<0.001*
Hypothyroidism	53 (18%)	26 (18%)	0.955
Hypertension	43 (14%)	15 (10)	0.204
Drug History			
Aspirin	17 (6%)	3 (2%)	0.077
Atorvastatin	25 (8%)	3 (2%)	0.009*
Levothyroxine	38 (13%)	21 (14%)	0.673
Losartan	18 (6%)	7 (5%)	0.571
Metformin	24 (8%)	5 (3%)	0.059
Pantoprazole	22 (7%)	9 (6%)	0.611
Habitual History			
Smoking	Never Smoked: 239 (80) Smoker: 23 (8%) Rare Smoker: 20 (7%) EX-Smoker: 10 (3%) Occasional Smoker: 7 (2%)	Never Smoked: 123 (83%) Smoker: 6 (4%) Rare Smoker: 8 (5%) EX-Smoker: 9 (6%) Occasional Smoker: 3 (2%)	0.383

RH, Restrictive to Hypoabsorptive; HH, Hypoabsorptive to Modified-Hypoabsorptive; SG, Sleeve Gastrectomy; OAGB, One-Anastomosis Gastric Bypass; LAGB, Laparoscopic Adjustable Gastric Band; RYGB, Roux-en-Y Gastric Bypass; LGP, Laparoscopic Gastric Plication; VBG, Vertical Banded Gastroplasty; JIB, Jejunoileal Bypass; SASI-B, Single Anastomosis Sleeve Ileal Bypass; GP, Gastric Partitioning; DS, Duodenal Switch; SADI-B, Single Anastomosis Duodenoileal Bypass; SASJ-B, Single Anastomosis Sleeve Jejunal Bypass.

* Statistically significant

Table 2- Baseline Weight-Related Characteristics of the Study Participants

Weight-related characteristics (kg/m^2)	RH group	HH group	p-value†
BMI1: BMI before first surgery	50.2 ± 28.5	49.8 ± 10.5	0.858
BMI2: Nadir BMI after first surgery	34.7 ± 29.0	30.6 ± 8.0	0.292
BMI3: BMI before revisional surgery	42.9 ± 7.1	39.3 ± 9.4	**<0.001***
BMI4: Nadir BMI after revisional surgery	31.8 ± 6.2	31.9 ± 6.5	0.916
Time interval between two surgeries (years)	6.9 ± 3.5	6.7 ± 4.6	0.080
D (Nadir): BMI4 – BM2	- 2.8 ± 3.2	1.7 ± 6.3	0.271
Successful catch of previous Nadir – (%)	50.3%	44.4%	0.900
D (BMI from base): BMI4 – BM1	- 18.0 ± 9.3	- 17.8 ± 9.7	0.088

RH, Restrictive to Hypoabsorptive; HH, Hypoabsorptive to Modified-Hypoabsorptive

† All the p-values are obtained from the pooled results of all univariate linear regression models (logistic for variable 'percentage of successful catch of previous Nadir') from all 50 rounds of imputation employing the MICE algorithm.

* Statistically significant

Table 3- Total Weight Loss (TWL%) Comparison Between Groups

Time point (n)	RH group	HH group	p-value
10D (n=418)	3.87 ± 4.46 (n=286)	2.43 ± 5.90 (n=132)	0.082
1M (n=402)	7.78 ± 4.60 (n=273)	4.65 ± 6.79 (n=129)	**<0.001***
3M (n=382)	14.47 ± 5.60 (n=258)	7.94 ± 11.10 (n=124)	**<0.001***
6M (n=360)	20.26 ± 7.91 (n=241)	10.22 ± 15.14 (n=119)	**<0.001***
9M (n=314)	23.42 ± 8.86 (n=209)	12.84 ± 16.29 (n=105)	**<0.001***
12M (n=312)	25.03 ± 10.85 (n=217)	13.76 ± 17.87 (n=95)	**<0.001***
18M (n=264)	26.71 ± 11.41 (n=183)	15.25 ± 17.72 (n=81)	**<0.001***
24M (n=239)	25.87 ± 12.09 (n=165)	15.22 ± 18.09 (n=74)	**<0.001***
36M (n=180)	24.20 ± 13.23 (n=123)	11.66 ± 18.53 (n=57)	**<0.001***
48M (n=133)	22.77 ± 13.79 (n=89)	15.24 ± 18.08 (n=44)	**0.044***
60M (n=101)	21.21 ± 15.18 (n=68)	15.83 ± 16.93 (n=33)	0.160

RH, Restrictive to Hypoabsorptive; HH, Hypoabsorptive to Modified-Hypoabsorptive

* Statistically significant

Table 4- Predictors of BMI Before Revisional Surgery

Predictor	β	p-value
Surgery Group (HH vs. RH)	−2.72	**<0.001***
Sex (Female vs. Male)	0.02	0.981
Age	−0.12	**<0.001***
Smoking (Ever)	−0.78	0.667
T2DM	0.86	0.501
FBS 100–125	0.32	0.818
Dyslipidemia	0.52	0.559
Hypothyroidism	1.35	0.317
Hypertension	0.09	0.939
Aspirin	1.08	0.487
Atorvastatin	−1.01	0.508
Levothyroxine	−0.79	0.604
Losartan	**+3.28**	**0.067**
Metformin	−1.70	0.246
Pantoprazole	−1.24	0.298
Interval between surgeries (years)	0.56	**<0.001***
BMI before primary surgery	0.21	**<0.001***
Minimum BMI after primary surgery	0.62	**<0.001***

RH, Restrictive to Hypoabsorptive; HH, Hypoabsorptive to Modified-Hypoabsorptive

Model fit: $R^2 = 0.58$ (95% CI: 0.50–0.66)

* Statistically significant

Table 5- Multivariate linear regression models to predict TWL after 18 and 24 months post-revisional surgery

Predictor	β (18M)	p-value (18M)	β (24M)	p-value (24M)
Demographics and Habitual History				
Gender				
Male	Reference		Reference	
Female	-0.33	0.919	2.27	0.495
Age (years)	-0.16	0.160	-0.18	0.082
Smoking (ever)				
Never Smoked	Reference		Reference	
With History of Smoking	-1.82	0.438	-1.66	0.509
Weigh Related variables and Revisional Surgery Approach				
Surgery group				
RH	Reference		Reference	
HH	-5.07	**0.026***	-4.31	**0.048***
Interval between surgeries (years)	0.41	0.417	0.3	0.622
BMI before first surgery	-0.52	**0.027***	-0.5	**0.016***
Nadir BMI after first surgery	0.13	0.729	0.18	0.681
BMI before revisional surgery	1.24	**<0.001***	1.26	**<0.001***
Past Medical History				
Type 2 Diabetes Melitus				
No	Reference		Reference	
Yes	-3.19	0.347	-2.26	0.534
Impaired Glucose Tolerance				
No	Reference		Reference	
Yes	-2.94	0.467	-3.05	0.509
Dyslipidemia				
No	Reference		Reference	
Yes	3.58	0.305	3.51	0.248
Hypothyroidism				
No	Reference		Reference	

Yes	6.09	0.166	5.87	0.211
Hypertension				
No	Reference		Reference	
Yes	0.08	0.982	-2.29	0.517
Drug History				
Aspirin	-7.12	0.125	-8.31	0.062
No	Reference		Reference	
Yes				
Atorvastatin				
No	Reference		Reference	
Yes	2.71	0.529	0.48	0.918
Levothyroxine				
No	Reference		Reference	
Yes	-7.18	0.128	-4.51	0.363
Losartan				
No	Reference		Reference	
Yes	1.27	0.821	-0.07	0.99
Metformin				
No	Reference		Reference	
Yes	-1.18	0.78	2.27	0.589
Pantoprazole				
No	Reference		Reference	
Yes	-0.48	0.899	-2.82	0.459

RH, Restrictive to Hypoabsorptive; HH, Hypoabsorptive to Modified-Hypoabsorptive
Model fit: R^2 (18M) = 0.51 (95% CI: 0.39–0.61); R^2 (24M) = 0.50 (95% CI: 0.38–0.61).

* Statistically significant

Figures

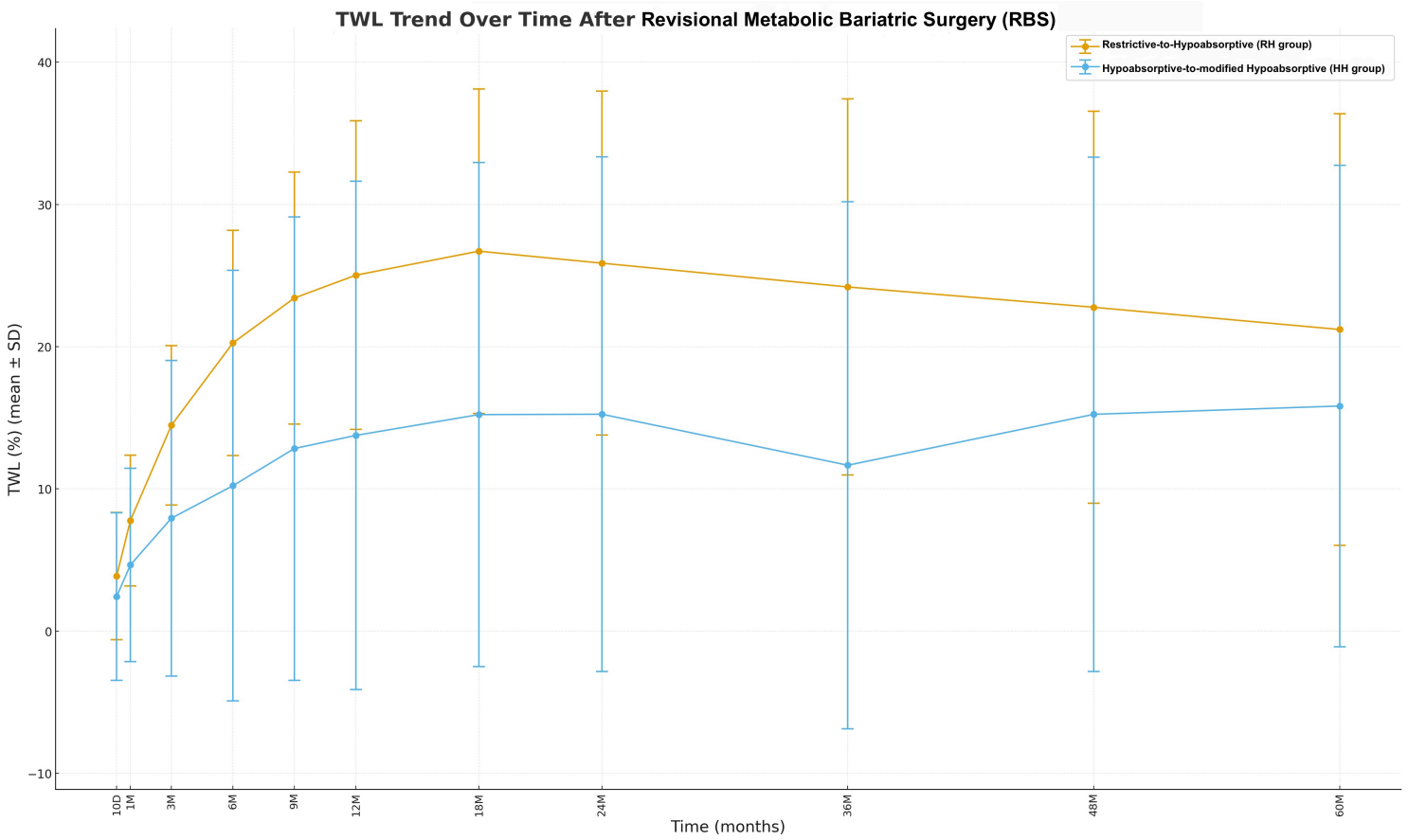


Figure 1

TWL trend over time in two different revision surgery groups