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ORIGINAL CONTRIBUTIONS

# Laparoscopic Magenstrasse and Mill Gastroplasty (M&M): Midterm Results

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## Abstract

**Background** The Magenstrasse and Mill gastroplasty (M&M) is a gastric restrictive procedure without band or stomach resection. Short-term evaluation of the laparoscopic procedure showed low morbidity and satisfactory results on weight loss. Evidence of the validity of the technique in the longer term is scarce.

**Methods** Data from patients who underwent M&M procedure from May 2012 to September 2015 were retrospectively reviewed. Preoperative clinical characteristics and data up to 4 years after operation were analyzed.

**Results** A total of 132 patients were included in this study with a mean age of 46 ± 13.4 years. The mean body mass index (BMI) at the time of procedure was 43 ± 4.5 kg/m$^2$. Mean percentage of excess weight loss (%EWL) was 67, 67, 58, and 57% at 1, 2, 3, and 4 years, respectively. The remission rate for diabetes was 36%. About half of the insulin-dependent patients could stop their insulin treatment. Hypertension was resolved in 33.8% of the patients after 4 years. Incidence of vitamin and mineral deficiency was low throughout the study period, less than or equal to 3% for vitamin B12 and 1% for ferritin. Incidence of gastroesophageal reflux did not exceed 15% during the study. Over 75% of the patients reported a good or very good quality of life following the surgery.

**Conclusion** These results confirm the validity of M&M as a bariatric procedure. The low incidence of vitamin deficiencies and gastroesophageal reflux might be the important asset of M&M over other existing techniques.

**Keywords** Laparoscopic · Sleeve · Gastroplasty · Magenstrasse and Mill · Obesity · Surgery

## Introduction

Bariatric surgery has demonstrated its efficacy in the treatment of morbid obesity in terms of weight loss and obesity-related morbidities resolution [1]. Over time, numerous types of procedures have been described with proven effectiveness but also with their specific complications and side effects.

Malabsorptive procedures often lead to micronutrient deficiencies which require lifetime supplementation. Dumping syndrome or hypoglycemia are well-known side effects of laparoscopic Roux-en-Y gastric bypass (LRYGB) [2]. Re-intervention is necessary in case of internal hernia and bowel obstruction [3]. Because of these side effects and the fact that LRYGB is technically demanding, restrictive procedures appear to be more and more attractive over the years. Laparoscopic sleeve gastrectomy (LSG) has become the most popular method of weight loss surgery, accounting for more than half of all weight loss operations, exceeding in the number of laparoscopic gastric bypass [4]. LSG has the advantages of satisfactory early to long-term weight loss results, comorbidity resolution, and low postoperative complication rates [5–7]. However, severe side effects such as vitamin deficiencies, gastroesophageal reflux disease (GERD), and portomesenteric vein thrombosis are reported [8–10].

The search for the ideal procedure leads us to re-evaluate Magenstrasse and Mill (M&M) procedure (Fig. 1). M&M was

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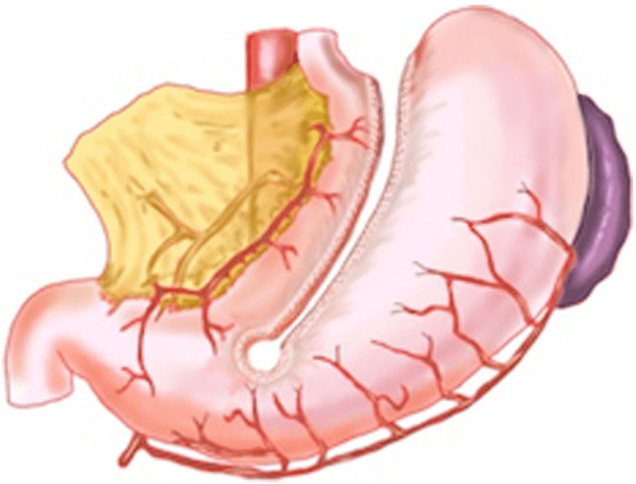

**Fig. 1** The Magenstrasse and Mill procedure

first described in 1987 by Johnston et al. [11]. In this method, a long narrow gastric tube is fashioned by a stapling along the lesser curvature (Magenstrasse) which drain into the antrum (Mill), avoiding gastric resection.

In a previous study, we showed that the laparoscopic approach of M&M was feasible with low morbidity and effective weight loss comparable with other procedures [12]. In this study, we report midterm outcome data for laparoscopic M&M, including weight loss, changes in the incidence of obesity-related diseases, and health-related quality of life (HRQOL) scores.

## Methods

### Patients Selection

From May 2012 to September 2015, all consecutive patients who underwent M&M procedure were identified. Patients with a follow-up < 1 year and incomplete data were excluded from this analysis. Data were retrospectively retrieved from a prospectively maintained database. The data included demographic variables, preoperative characteristics, and short- and long-term outcomes. The laparoscopic approach of the procedure was evaluated in the Department of Abdominal Surgery of the CHU of Liège in a previous prospective study after approval of the local ethical committee (NCT02050477).

### Preoperative Evaluation

All the patients met the international criteria for bariatric surgery. They were evaluated by a multidisciplinary team specialized in bariatric and metabolic surgery including a surgeon, endocrinologist, psychologist and/or psychiatrist, and dietician. Their alimentary behavior (especially their ability to avoid interprandial feeding) was characterized after dietetic evaluation. All of the patients underwent a preoperative work-up, including abdominal ultrasound and upper GI endoscopy with Helicobacter pylori screening.

### Surgical Technique

All the procedures were performed laparoscopically by the same surgeon. The operative procedure was previously described [12]. Briefly, the greater omentum was opened, preserving the gastroepiploic vessels, to expose the posterior aspect of the stomach. Then, a circular stapling midway between the angularis incisura and the greater curvature was fired. A longitudinal stapling was done along the calibration tube (40 Fr for 41 and 50 Fr for 91 patients), from the circular opening toward the angle of Hiss.

### Follow-up and Postoperative Outcome

To prevent deep venous thrombosis, patients received a daily subcutaneous injection with low-molecular-weight heparin for 20 days postoperatively. Proton-pump inhibitors (PPIs) were prescribed for 1 month. A multivitamin complex (Omnibionta Pronatal, Merck, Darmstadt, Germany) was prescribed for 6 months.

Patients were followed by the multidisciplinary team at 1, 3, 6, and 12 and 18 and 24 months postoperatively and annually thereafter. Follow-up visits included weight measurement, clinical history, examination, and laboratory tests for blood glucose as well as nutrition deficiency.

Comorbidities were recorded at each visit. Remission of hypertension (HTN) was defined as a blood pressure below 140/90 mmHg without medication. Remission of diabetes mellitus (DM) was defined as HbA1c level below 6.4% without medication. Improvement of DM was defined as HbA1c level below 6.4% with decrease in number or dosage of medication. Remission of sleep apnea was based on patient's statement and no usage of continuous positive airway pressure machine. Ideal weight for the percentage of excess weight loss (%EWL) was calculated as the weight at a body mass index (BMI) of 25 kg/m$^2$.

Gastroesophageal reflux disease (GERD) was also evaluated. GERD was defined as a clinical symptom (heartburn or regurgitation) associated with medication.

The Moorehead-Ardelt questionnaire was used to measure HRQOL for this study (Appendix 1). The Bariatric Analysis and Reporting Outcome System (BAROS) [13] is a unique scoring method to evaluate, in a single page, the results after bariatric surgery. Points are added or deducted according to weight loss, improvements in comorbidities, and changes in QOL. Points are deducted for complications and reoperations, before obtaining a final score that classifies outcomes in five categories: failure, fair, good, very good, and excellent. Weight evolution was analyzed in terms of percentage of

excess body mass index loss (% EBMIL), calculated as: (initial BMI – current BMI)/(initial BMI – 25) × 100. A weight regain was scored with − 1 point and different weight loss was scored as follows: 0–25% with 0 points; 25–50% with 1 point; 50–75% with 2 points; and > 75% with 3 points. The medical comorbidities were classified as: aggravated (one point less), unchanged (0 points), improved (1 point), one major resolved (2 points), and more than one morbidity resolved (3 points).

### Statistical Analysis

Categorical variables are expressed in numerical figures and percentages. They were compared using Fisher's exact test or the $\chi^2$ test as appropriate. Continuous variables were expressed as mean ± standard deviation and were compared using the Kruskal-Wallis test. Statistical significance was accepted at the 0.05 level.

## Results

### Studied Population

During the study period, 211 patients underwent M&M procedure. Among them, 79 patients had less than 1 year of follow-up and therefore were excluded from the data analysis. A total of 132 patients were included in this study with a mean age of 46 ± 13.4 years (range 18–72). Mean BMI at the time of procedure was 43 ± 4.5 kg/m$^2$ (range 37.1–57.1). Patients' baseline characteristics are detailed in Table 1**.** The mean follow-up was 37 ± 9.7 months (range 12–48), with 100% 1-year follow-up and 66% 3-year follow-up. No leak or other surgical complications were reported.

A total of 6 patients underwent a conversion to LRYGB. For all of these patients, the reason of conversion was weight loss failure. When we analyzed the preoperatory assessment, we noticed that all patients were grazers and sweet-eaters. The reason for performing M&M procedure instead of a malabsorptive procedure was iron and/or B12 deficiency in 2 patients and Crohn's disease in 1 patient. Three patients chose M&M procedure while the obesity center team rather recommended a gastric bypass.

**Table 1** Baseline characteristics of the patients

| | |
|---|---|
| Number of patients | 132 |
| Female | 75 |
| Male | 57 |
| Age | 46 ± 13.4 years (range 18–72) |
| Body mass index | 43 ± 4.5 kg/m$^2$ (range 37.1–57.1) |
| Comorbidities | |
| Hypertension | 68 (51.5%) |
| Diabetes mellitus | 33 (25%) |
| Sleep apnea | 28 (21.2%) |
| Hyperlipidemia | 104 (78.8%) |

### Weight Loss

Mean BMI decreased from 43 ± 4.5 to 31.5 ± 4 kg/m$^2$, 31.6 ± 4.7 kg/m$^2$, 32.9 ± 5.2 kg/m$^2$, and 33.1 ± 5.6 kg/m$^2$, respectively at 1,2, 3, and 4 years after surgery. (Table 2, Fig. 2).

Percentage of excess weight loss (%EWL) was 67 ± 30.4% at 1 year, 67 ± 28.2% at 2 years 58 ± 25.1% at 3 years, and 57 ± 26.7% at 4 years after procedure.

We used 2 different calibration tubes (40Fr for 41 and 50Fr for 91 patients) during the study period. The two groups were comparable regarding baseline characteristics including age ($P = 0.81$), preoperative BMI ($P = 0.44$), gender ($P = 0.92$), and preoperative GERD ($P = 0.35$).

We compared the two groups in terms of weight loss and reflux (Table 3). The %EWL was slightly higher in the group 40Fr than 50Fr but the difference was not significant. There was no significant difference in the GERD rate.

A comparison between patients younger and older than 40 years was performed. (Table 4). The average age of 2 groups was 30.1 ± 5.9 and 53.7 ± 6.8 years, respectively. The two groups were comparable regarding baseline characteristics including preoperative BMI ($P = 0.36$) and gender ($P = 0.81$). Older patients experienced lower weight loss than younger patients. The difference became statistically significant after 2 years.

### Comorbidities

A total of 33 patients (25%) suffered from type II diabetes mellitus (DM) at the time of surgery. The mean age of this diabetic population was 54 ± 8.9 years. The mean HbA1c level was 7.6% preoperatively and decreased to 6.4, 6.8, 7, and 7% respectively at 1, 2, 3, and 4 years postsurgery. Of these 33 diabetic patients, 15 were on insulin. Fifty-three percent ($n = 8$) of the patients could stop insulin at 1 year after surgery and only one patient had to start again with insulin treatment. All the other patients ($n = 7$) who remained under insulin treatment could lower the doses after surgery. Out of the 33 diabetic patients, 27 were on oral anti-diabetic (OAD) drugs (82%). This decreased to 47% at 1 year postsurgery and

**Table 2** Weight loss evolution

| | *N* available for follow-up (%) | BMI (kg/m$^2$) | %EWL |
|---|---|---|---|
| 1 year | 132 (100) | 31.6 | 67 |
| 2 years | 117 (88.6) | 31.6 | 67 |
| 3 years | 87 (66) | 32.9 | 58 |
| 4 years | 78 (59) | 33.1 | 57 |

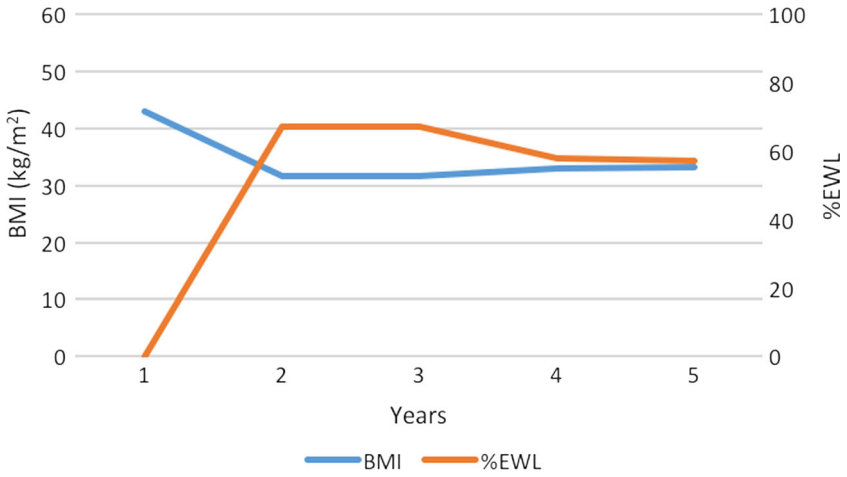


**Fig. 2** Weight loss evolution

remained lower than 50% throughout the follow-up. The remission rate of diabetes was 36% ($n = 12$).

At preoperative work-up, 104 patients (78.8%) showed hyperlipidemia. This percentage dropped to 60% at 1 year, 55% at 2 years, 53% at 3 years, and 56% at 4 years after surgery.

Out of 68 patients (52%) with hypertension at the time of surgery, 23 (33.8%) had their hypertension resolved and 45 (66.2%) could decreased their treatment.

Out of 27 (20.5%) patients with obstructive sleep apnea, 19 (67.8%) had it resolved at 1 year after the procedure.

### Evolution of Multivitamin Supplementation Compliance and Blood Vitamin Levels

All the patients received a multivitamin complex for 6 months after surgery. Then, the vitamin supplementation rate decreased progressively to 45% at 1 year, 17% at 2 years, and 5% at 3 years and more (Table 5).

Only a minority of patients had postoperative vitamin levels below normal range. No more than 3% of the patients had low vitamin B12 levels at any time points while only 1% had low ferritin levels. The postoperative values did not differ significantly from preoperative levels.

### Gastroesophageal Reflux

Incidence of GERD was 14% ($n = 18$) preoperatively. This percentage remained stable at 15%, 14.8%, 15.3%, and 15.1% at 1, 2, 3, and 4 years postsurgery, respectively. The incidence of new onset gastroesophageal reflux was 11% ($n = 15$).

### Health-Related Quality of Life

The quality of life data included 70 patients who completed the HRQOL questionnaire (response rate 53%). The survey was conducted at a median of 37 months (range 12–48) after M&M procedure. The analysis of the Moorhead-Ardelt Quality of Life Questionnaire showed improvement of the scores for each of six dimensions, summarized in Table 6. The quality of life was also analyzed in terms of complications and resolution of different medical conditions included in the BAROS score. The quality of life was defined as good or better for 53 patients (75.7%), fair for 22.9%, and a failure for 1.4% (Fig. 3).

## Discussion

M&M procedure was first described in 1987 but did not gain widespread acceptance. This may be partly related to the expansion of the laparoscopy at the same period and the difficulty to adapt this procedure to a mini-invasive approach.

We previously demonstrated that M&M could be performed using the laparoscopic technique with a low complication rate [12]. Our previous study also removed the

**Table 3** Weight loss and GERD according to groups of calibration tube

| | 40Fr group ($N = 41$) | 50 Fr group ($N = 91$) | $P$ value |
|---|---|---|---|
| %EBWL 1 year | 67.1 | 62.4 | 0.21 |
| %EBWL 2 years | 67.9 | 65.3 | 0.57 |
| %GERD 1 year | 8.1 | 16.1 | 0.80 |
| %GERD 2 years | 7.3 | 16.1 | 0.63 |

**Table 4** Weight loss according to age groups

| | < 40 years' group ($N = 45$) | > 40 years' group ($N = 87$) | $P$ value |
|---|---|---|---|
| %EBWL 1 year | 67.4 | 66.4 | 0.86 |
| %EBWL 2 years | 79 | 61.3 | 0.002 |
| %EBWL 3 year | 67.9 | 51.2 | 0.002 |
| %EBWL 4 years | 68.1 | 49.7 | 0.015 |

**Table 5** Percentage of abnormal levels of vitamins

| | Baseline ($N = 132$) | | 1 year ($N = 132$) | | 2 years ($N = 94$) | | 3 years ($N = 58$) | | 4 years ($N = 44$) | | $P$ value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference range | Low | High | Low | High | Low | High | Low | High | Low | High | |
| Vitamin A (0.35–1.75 μmol/L) | 3.2% | 2.7% | 2.4% | 2.6% | 3.1% | 1.8% | 1.6% | 0.5% | 1.3% | 0.7% | 0.54 |
| Vitamin E (18–29 μmol/L) | 6.5% | 3.1% | 2.4% | 1% | 9.1% | 5.2% | 4.9% | 3.6% | 2% | 2.8% | 0.08 |
| Vitamin B12 (150–750 pmol/L) | 1.6% | 2.7% | 3.3% | 0.9% | 1.2% | 0.7% | 2.1% | 0.7% | 3.2% | 0.3% | 0.21 |
| Folic acid (4–22 nmol/L) | 2.5% | 4.7% | 2.7% | 6.2% | 4.5% | 1.6% | 3.6% | 0.2% | 4% | 1.3% | 0.09 |
| Ferritin (18–300 μg/L) | 1.4% | 11.3% | 1.4% | 15% | 1.2% | 10.2% | 1.1% | 4.4% | 1.3% | 1% | 0.34 |

*N* shows the number of patients with level of vitamins available at each check point

doubt about greater stomach drainage. Postoperative upper GI opacification was performed systematically for the first 100 procedures and showed preferential emptying in the duodenum with only partial filling of the fundus. This confirmed the results of Carmichael et al. who reported no alterations in gastric emptying studies [14]. With the current follow-up, no clinical complications linked to the preservation of the greater curvature of the stomach were observed.

Weight loss reports of M&M procedure consisted mainly of the studies of the original series. Johnston et al. [11] reported a series of 100 patients operated between 1992 and 1998. Their study reported EWL of 60% at 1 year after M&M, the weight being unchanged over the second and third year. Our results were similar to their experience. Percentage of EWL was 67% after the first and second postoperative year; it decreased to 58% and 57% after 3 and 4 years, respectively. Carmichael et al. [15] also reported 59% EWL at 3 years. The earlier satiety but also the reduced sensation of hunger described by the patients after the procedure seems to play a major role. During the study period, we used two different bougies size (BS) (50Fr and then 40Fr). By creating a narrower stomach capacity, we expected to improve weight loss. A correlation between the use of smaller bougies and greater weight loss has been reported after LSG [16]. This was not confirmed in our study. The reason may be the limited difference in diameter of the 2 bougies associated with the smaller length of stomach division in the M&M compared with LSG. It may also be due to an adaptation of the food behavior of the patients.

We observed in this study an improvement of obesity-related morbidities after surgery. Our remission rate of diabetes was 36%. This is in agreement with previous studies that report remission rates between 21 and 63% after bariatric surgery [17–21]. Furthermore, these results are to be interpreted with known preoperative factors with a negative effect on diabetes remission, including insulin use and older age [19–22]. Fifteen out of our 33 diabetic patients were on insulin. In an insulin-dependent diabetic population, Guio et al. [17] reported a 27% diabetes remission rate after Roux-en-Y gastric bypass with a relapse in 65% after a mean follow-up of $4.9 \pm 1.9$ years. Furthermore, our diabetic population was rather old, with a mean age of 54 years.

Minerals and vitamin deficiencies are well known after malabsorptive procedures, but recent studies revealed that LSG patients also are at risk. Pellitero et al. found 50% of

**Table 6** Quality of life in patients following M&M procedure $N = 70$

| | Much worse | Worse | The same | Better | Much better |
|---|---|---|---|---|---|
| Self esteem | 0 | 0 | 7 (10%) | 31 (44.3%) | 32 (45.7%) |
| Physical activities | 0 | 0 | 8 (11.4%) | 20 (28.6%) | 42 (60%) |
| Social activities | 0 | 9 (12.9%) | 20 (28.6%) | 20 (28.6%) | 21 (30%) |
| Working performance | 0 | 4 (5.7%) | 22 (31.4%) | 22 (31.4%) | 22 (31.4%) |
| Sexual interest | 0 | 0 | 45 (64/3%) | 19 (27.1%) | 6 (8.6%) |
| Food approach | 2 (2.9%) | 3 (4.3%) | 20 (28.6%) | 15 (21.4%) | 30 (42.8%) |

*N*, number of patients included in the HRQOL data

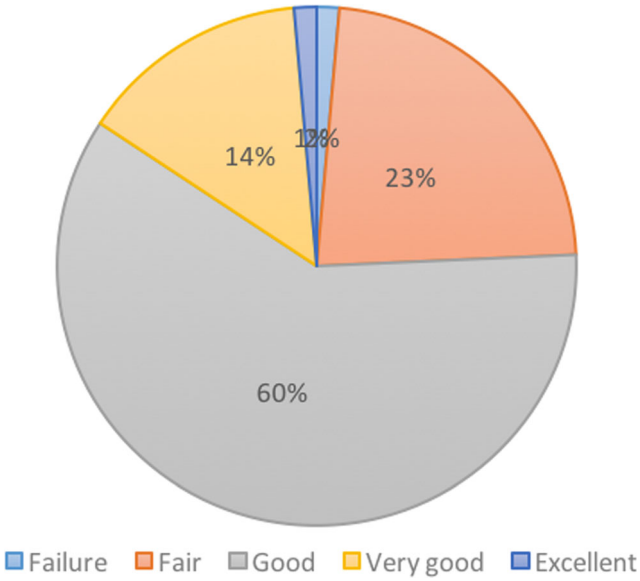


**Fig. 3** Outcome group according to BAROS scoring table

micronutrient deficiency despite supplementation [8]. Similarly, Ruiz-Tovar et al. concluded their study with the necessity of a "lifelong close nutritional follow-up" after LSG to detect micronutrient deficiencies and to add specific supplements [23]. M&M preserves the entire stomach, maintaining acid secretion and intrinsic factor production. Postoperative biological controls in our study confirmed the very low rate of vitamins or mineral abnormalities.

Another major complication after LSG is the high incidence of postoperative GERD. In a recent study, Viscido et al. observed 36.9% of new-onset symptoms and 28.7% of de novo erosive esophagitis [24]. Althuwaini et al. reported 47.06% of new-onset heartburn [25] similar to the 52% of new-onset GERD observed by Coupaye et al. [26]. In a meta-analysis, Jelmer et al. revealed up to 20% of new onset GERD after surgery [9]. Different mechanisms are believed to potentially cause postoperative GERD after sleeve gastrectomy such as high intragastric pressure, decline in gastric compliance, and "neofundus" formation. We reported in this study a much lower prevalence of new-onset GERD (11.9%). We hypothesize that the preservation of the antro-pyloric function induces less intragastric pressure, and consequently less GERD compared with LSG.

This finding might be one of the reasons for the important improvement in quality of life in our study, with 76% of patients describing a good to excellent HRQOL after surgery. Carmichael et al., who assessed the HRQOL in 82 patients after M&M also reported that the majority of patients (88%) were pleased with the result of the surgery [27].

The organ preservation offers other potential advantages compared with LSG; the absence of gastrectomy allows minimal dissection. The more limited surgical trauma that avoids the dissection of the greater curvature and the ligation of short gastric vessels could decrease the risk of portomesenteric thrombosis (PMVT). PMVT is a rare (less than 1%) but dramatic surgical complication following LSG [10].

The absence of organ to extract limits the parietal trauma. Port site hernia (PSH) is a rare but potentially serious complication of LSG. The overall incidence was 2.8% in recent data [28] and the majority of hernias occurred at the level of the port used for stomach retrieval. The same study reported a 5% incidence of port site infection, most often located at the site of gastric extraction. M&M was not associated in our study with port site complication.

The removal of the greater curvature of the stomach in LSG is believed to explain the results obtained in terms of weight loss and improvement of comorbidities by hormonal modifications. However, the present study demonstrated an improvement of weight loss and obesity-associated morbidities without gastrectomy. This suggests that factors other than hormonal changes intervene. The effectiveness of adjustable gastric banding and vertical banded gastroplasty procedures that preserve stomach integrity largely supports the multiplicity of pathways involved [29, 30]. The role of the vagal nerve in the putative mechanism of weight loss after bariatric surgery should not be underestimated. Indeed, afferent fibers from the vagus nerve play a crucial role in the neural mechanism of satiation [31]. Recent studies also indicate that weight loss per se is the main factor leading to diabetes remission after bariatric surgery [18, 20].

This study has several limitations. Aside from those inherent to a retrospective study, the lack of objective measurements does not provide robust evidence on the effects of M&M on GERD or sleep apnea syndrome. Moreover, the limited sample size of the population does not allow us to draw firm conclusions on the metabolic effects of the procedure. This study nevertheless confirms the safety of the laparoscopic approach and provides evidence on the validity of M&M as an effective bariatric procedure in terms of sustained weight loss along with a greatly improved quality of life. The procedure was also associated with low incidence of GERD and of micronutrient deficiency, which are both major advantages of M&M. These results need to be validated in larger studies.

**Compliance with Ethical Standards** The authors declare that they have no conflict of interest.

**Ethical Approval** For this type of study, formal consent is not required.

## Appendix

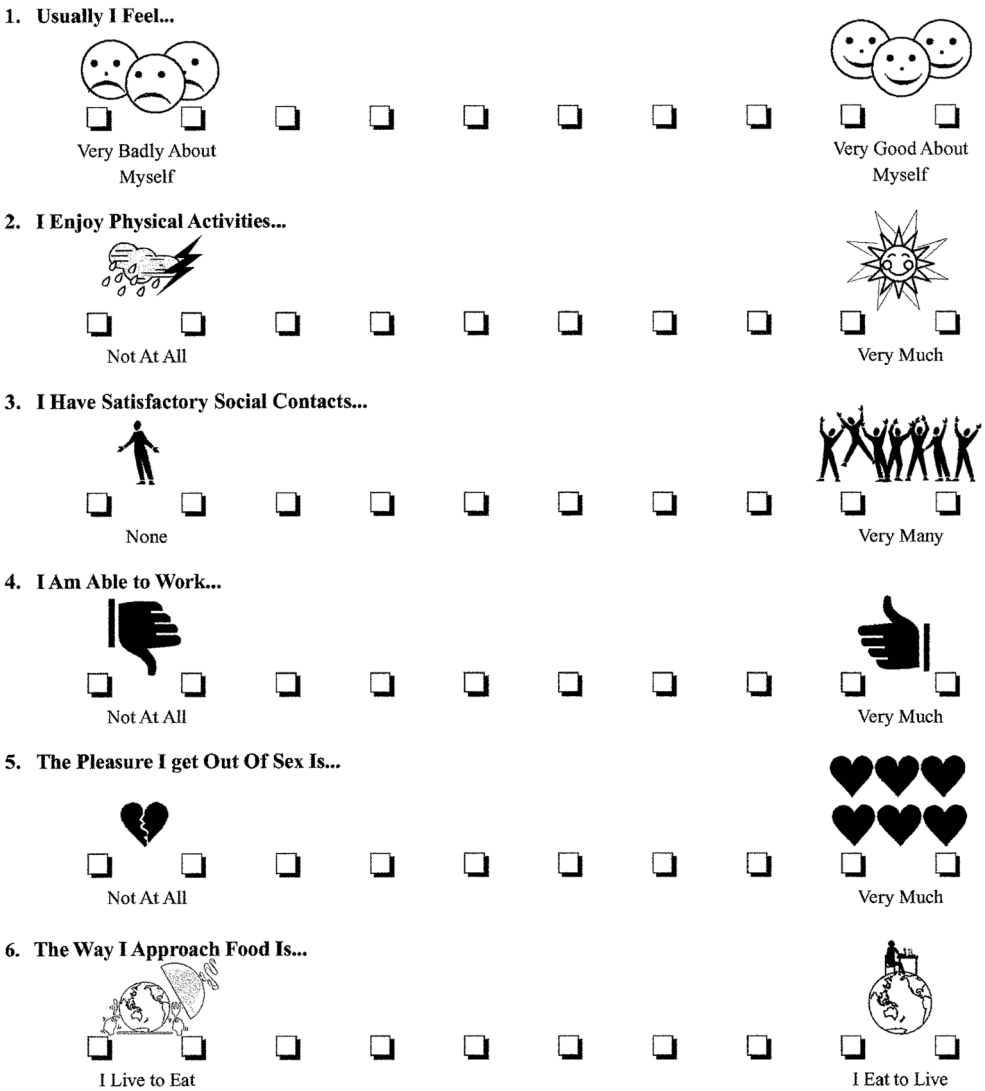


**Fig. 4** Moorehead-Ardelt questionnaire

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