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Comparative characteristics of patients with type 2 Diabetes mellitus treated by bariatric surgery versus medical treatment: a multicentre analysis of 277,862 patients from the German/Austrian DPV database

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Abstract:

**Introduction:** Bariatric surgery is a well established treatment option for serious obesity and concomitant type 2 diabetes mellitus (T2DM). In this analysis, we investigated predictors for bariatric surgery in everyday clinical practice.

**Materials and Methods:** In the DPV-registry, patients with T2DM from Germany and Austria treated by bariatric surgery were compared to non-surgery controls by descriptive statistics and regression analysis.

**Results:** Among 277,862 patients with T2DM, 0.07% underwent bariatric surgery. Surgery patients were predominantly female [61.20%], younger [median age (Q1;Q3):54.74(47.40;61.61) vs. 70.04(60.36;77.58)yr] and had a longer diabetes duration [11.21(7.15;17.93) vs. 8.36(2.94;14.91)yr]. They had a higher BMI [40.02 vs. 30.61kg/m², adjusted p<0.0001], and a slightly lower HbA1c [7.25 vs. 7.56%, adjusted p<0.05]. There was a trend using more often Insulin therapy (52.79 vs.50.08%, n.s.) with no difference in insulin dose/kg*d [0.56 vs. 0.58, n.s.]. Sleeve-gastrectomy was performed most frequently, followed by Roux-en-Y gastric bypass, gastric banding, gastric balloon and others. 2-year-follow-up data in 29 patients demonstrated significant reductions in BMI [45.23 to 38.00kg/m², p<0.005] and HbA1c [7.98 to 6.98%, p<0.005], and a trend for reduced insulin requirements [62.07 vs. 44.83%, n.s.].

**Conclusion:** Despite favourable 2-year outcomes, bariatric surgery is still used rarely in patients with T2DM and obesity. BMI rather than metabolic control seems to represent the major selector for or against bariatric surgery in T2DM.

**Key Words:** Type 2 Diabetes, bariatric surgery, medical treatment
Introduction:

The global prevalence of type 2 diabetes mellitus (T2DM) is increasing rapidly and is one of the major threats to human health worldwide [1, 2]. This goes in parallel with the current obesity epidemic [3], because obesity and T2DM are two interrelated diseases. T2DM is the most important comorbidity of obesity and leads to micro- and macrovascular long-term complications such as cardiovascular events, blindness, renal failure and neuropathy, which together cause high morbidity and mortality with reduced life expectancy [4]. The majority of primary care physicians continue to recommend lifestyle changes with appropriate diet, exercise and different glucose lowering drugs for the treatment of T2DM. In addition to glycaemic control and weight loss, an aggressive multifactorial management of cardiovascular risk factors is essential to prolong the life of patients with T2DM and obesity [5]. However, a significant proportion of patients fail to achieve adequate combined target goals for control of glycaemia, blood pressure, lipids and body weight, and thereby reduction of cardiovascular risk [6].

Bariatric surgery is a well-established treatment option for marked obesity [7, 8]. Guidelines recommend bariatric surgery for patients with a body mass index (BMI) of more than 40 kg/m² or more than 35 kg/m² with comorbidities, if conservative treatment fails. Furthermore patients with BMI of 30 to 34.9 kg/m² and diabetes or metabolic syndrome may also be considered for a bariatric procedure [9]. Many randomized, controlled trials and observational studies have demonstrated that bariatric surgery significantly improves glycaemic control as well as diabetes remission, cardiovascular risk factors and mortality in this patient population [10-16]. In recent years, several randomised controlled trials indicated that bariatric surgery is superior to intensive medical treatment alone in achieving glycaemic control and reduction of cardiovascular risk factors in patients with T2DM [12, 14, 15, 17, 18].
Moreover, bariatric surgery has been shown to be also effective in patients with T2DM and a BMI below 35kg/m² [19], thereby establishing “metabolic surgery” as a treatment option for patients with T2DM. The above evidence led to a joint recommendation by Diabetes Associations to include metabolic surgery into the treatment algorithm for type 2 diabetic patients on a routine basis [20]. Whether these treatment options for T2DM patients with obesity are translated into daily clinical practice outside of randomized controlled trials is currently not known. Therefore, we conducted an analysis with data from a nationwide diabetes database in Germany and Austria with a comprehensive set of T2DM patients. The objective was to identify clinical situations that affect diabetologists’ recommendations for bariatric surgery in everyday practice. Furthermore, we investigated the metabolic changes after surgical treatment in real-life in patients with T2DM.

**Materials and Methods:**

**Patients and data collection:**

Anonymous data were retrieved from the computer-based, standardized, multicentre, follow-up diabetes patient registry, called the Diabetes Prospective Follow-up Initiative (Diabetes-Patienten-Verlaufsdokumentation, DPV; [www.d-p-v.eu](http://www.d-p-v.eu)). Currently, 420 specialized primary care physician practices, specialized diabetes departments of University Hospitals, community based general hospitals and rehabilitation units in Germany and Austria enter diabetes related data regularly, and transmit anonymized data twice a year to Ulm, Germany, for central analyses and benchmarking as described elsewhere [21, 22]. The DPV initiative has been approved by the Ethics Committee of Human Experimentation at Ulm University and the anonymized data collection by local review boards at each participating clinic.
Patients with T2DM, age ≥ 20 years, with and without bariatric surgery were included in this study. For the analysis of clinical characteristics and predictors for bariatric surgery (table 1), we analysed the most recent treatment year.

For the analysis of target parameters before and after bariatric procedures, we compared predefined “Index Periods” of 24 months before and after surgery, respectively. “Index Period 1” comprised an interval of −24 months to 0 months pre-surgery, and “Index Period 2” was defined as the interval of 0 to +24 months after surgery.

The final study population from 1995 up to March 2015 comprised 277,862 patients from 354 centers with T2DM, of whom 183 patients with T2DM were treated by bariatric surgery. For the comparison of index periods before and after bariatric surgery, 29 patients could be analysed.

**Statistical analysis**

Data were analysed using the SAS statistical software package, version 9.4 (SAS for Windows; SAS Institute, Cary, NC, USA). Results are given as median with quartile ranges or as proportions. For group comparisons, nonparametric statistical tests (Kruskall-Wallis test) were used. Differences of frequencies for categorical variables were tested by the \( \chi^2 \) test. A two-tailed \( p \) value ≤ 0.05 was considered statistically significant. We adjusted for multiple testing using Bonferroni step-down correction (Holm method).

To compare patient characteristics before and after surgery, paired student’s t-test was used for continuous variables and McNemar test was used for binary variables. To adjust for differences in age, sex and diabetes duration, multivariable regression modelling was used to compare clinical characteristics of patients with or without bariatric surgery. For continuous data, linear regression was applied, and logistic
regression was performed for binary data. The estimation method in linear regression was residual maximum pseudo likelihood (rmpl) and in logistic regression maximum pseudo likelihood with marginal expansion (mmpl). Between-within method was used to calculate denominator degrees of freedom. Adjustments were made for age, sex and diabetes duration; age was categorized by <40; 40 to 60 and ≥ 60 years, and diabetes duration by less than 5 and ≥ 5 years. Adjusted means were calculated based on observed marginal frequencies.

Results:

Patients Characteristics:

Baseline clinical characteristics of all T2DM patients with or without bariatric surgery from the DPV database are presented in table 1.

A total number of 277,862 patients with type 2 diabetes above the age of 20 years were included in this analysis. Of these patients 183 (0.07%) underwent a bariatric procedure, the majority of patients (277,679 patients; 99.93%) underwent no bariatric procedure. Patients with bariatric procedure were more frequently females (61.20%) in contrast to the group with no bariatric procedure (47.70%; p<0.005). Patients with bariatric procedures were significantly younger [median age with lower and upper quartile (Q1; Q3): 54.74 (47.40; 61.61) years vs. 70.04 (60.36; 77.58) years; p < 0.0001], and displayed a significantly longer diabetes duration [11.21 (7.15; 17.93) vs. 8.36 (2.94; 14.91) years; p < 0.0001]. After adjustment for age, sex and diabetes duration, the group with bariatric procedure had a significant higher BMI [40.21 kg/m² vs. 30.61 kg/m²; p < 0.0001], but lower HbA1c [7.25% vs. 7.56%; p < 0.05]. There was a slight trend towards using more often Insulin therapy in the group with bariatric procedure (52.79% vs. 50.08%; n.s.), but no difference in insulin dose (IE/kg*d) (0.56
vs. 0.58; n.s.). More than half of patients suffered from hypertension and/or dyslipidaemia. Only slightly more than a quarter of patients were treated with lipid lowering drugs in both groups with no significant differences. Antihypertensive treatment was more frequent, with more than half of patients using antihypertensive drugs in both groups. For frequencies of documented micro- and macrovascular complications, no significant differences were observed except in the frequency of diabetic foot syndrome (table 1).

**Bariatric procedures:**

Sleeve gastrectomy was the most common procedure (63 patients, 34.4%), followed by Roux-en-Y gastric bypass (61 patients, 33.3%), gastric banding (39 patients, 21.3%), gastric balloon (6 patients, 3.3%), and duodenal-jejunal-bypass-liner (EndobARRIER™; 5 patients, 2.7%); one patient (0.6%) underwent a biliopancreatic diversion with duodenal switch and one received gastric pacing. In 7 patients, the procedures were not specified in the database (table 2).

**Effects on BMI and HbA1c after bariatric procedure:**

29 patients (12 sleeve gastrectomy, 8 Roux-en-Y gastric bypass, 5 gastric banding, 3 duodenal-jejunal-bypass-liner and one gastric balloon) could be evaluated after bariatric procedure with complete two-year pre – and post-surgery data. In this subgroup of 29 patients, BMI was slightly higher at Index Period 1 (−24 months to 0 month) than in the whole bariatric-surgery population of 183 patients [median BMI with lower and upper quartile (Q1; Q3): [45.23 (40.33; 51.72) kg/m² vs. 41.91 (36.42; 47.65) kg/m²]. At Index Period 2 (0 to +24 months), weight loss and improvement of BMI, were substantial with a reduction of BMI from a median of 45.23 to 38.00 kg/m², \( p = 0.0004 \) (Table 3 and Figure 1A). The mean HbA1c at Index Period 1 was higher
in the subgroup of 29 patients (7.98% vs. 7.57% in the whole study population). Median levels of HbA1c were significantly reduced in the first 24 months after bariatric procedure from 7.98% to 6.98%, p = 0.003 (Table 3 and Figure 1B).

**Diabetes medication at baseline and after bariatric procedure:**
At Index Period 2, there was a trend towards less patients requiring insulin therapy compared to Index Period 1 for the total of insulin treated patients (62.07% vs 44.83%, n.s), and the insulin treated patients with concomitant medication (44.83% vs 27.59%, n.s), but not for patients on insulin treatment alone (17.24% vs 17.24%, n.s). However, the insulin dose per day was significantly reduced from 0.44 IE/kg*d to 0.41 IE/kg*d, p < 0.01 (Table 3 and Figure 2). Notably, however, data from only 12 patients out of 29 were available for analysing the insulin dose. The proportion of patients who were taking any glucose-lowering medication was stable at Index Period 2. The proportion of patients who did only lifestyle interventions and were not taking any glucose-lowering medications showed a trend towards an increase from 27.59 to 44.83% (Table 3). No changes in the use of antihypertensive or lipid lowering drugs were observed between the two time periods.

**Discussion:**
Bariatric surgery represents a potent treatment option for patients with T2DM and obesity. Many randomized, controlled trials and observational studies have shown that the three most common bariatric surgery procedures all significantly improve glycaemic control, cardiovascular risk factors and mortality in this patient population [10-16]. In the present analysis, we collected information from a nationwide diabetes patient care registry in Germany and Austria for comparison of patients with T2DM
treated by bariatric surgery or not. This dataset provides the advantage to investigate selection criteria for bariatric surgery in patients with T2DM and outcomes in ‘real life’ diabetes care. The scope of these results goes beyond those of randomized controlled studies, which in many instances do not adequately reflect broad translational medical care for patients in daily practice. It is important for healthcare professionals to understand whether bariatric surgery is being utilised as a treatment option in routine care for obese patients with T2DM. Our analysis of the DPV database which included large numbers of T2DM patients in diabetes care in Germany and Austria, found that only a very small proportion of obese patients with T2DM were undergoing bariatric surgery. This could potentially be explained in part to the fact that bariatric surgical clinics within Germany and Austria do not enter their patients into the DPV database. Furthermore, bariatric surgery is generally performed less frequently in Germany than in other European countries, USA/Canada, Latin/South America or Asia/Pacific. With only 8.8 bariatric procedures per 100,000 inhabitants, Germany is one of the countries with the lowest utilization of bariatric surgery in Europe. In contrast, the highest utilization in Europe is observed in Belgium with 107.2 per 100,000 inhabitants [7]. The observed sex distribution corresponds to the results in literature with higher representation of female sex [15, 23, 24]. The factors that underlie the low utilization of bariatric surgery in Germany are speculative and multilayer. This may be due to provider biases, insurance/payer barriers, patients’ reluctance and lack of surgeons and specialized obesity centres. Controlled bariatric surgery trials in patients with morbid obesity (BMI > 40 kg/m²) and T2DM demonstrate remission rates of 42% to 78% after Roux-en-Y bypass [14, 18, 25], and improvement of diabetes related comorbidity [8, 18, 26, 27]. Limited non RCT data in patients with T2DM with BMI < 30 kg/m² have also shown improved glycaemic control and diabetes remission, even before substantial weight loss.
Therefore bariatric surgery may in fact be metabolic in nature and perhaps be utilised in non-obese T2DM patients [19]. Furthermore, this intervention may represent a tool for prevention of T2DM by targeting patients with insulin resistance or impaired glucose tolerance [23]. Bariatric interventions in patients with T2DM have therefore been named “metabolic surgery” as opposed to the utilization of bariatric surgery in massively obese patients with or without concomitant diabetes mellitus that mainly targets body weight and less metabolic control [26]. The results of this “real life” analysis are in contrast to these developments. We found only a small number of T2DM patients with obesity in the diabetes database who were selected for bariatric surgery by their diabetologists. This indicates a lack of referrals from diabetologists to bariatric surgery. Currently, the major criterion for bariatric surgery seems to be represented by the BMI, and not the goal of improving glycaemic or metabolic control. Thus, in Germany and Austria, T2DM and metabolic control don’t seem to represent an important clinical argument for the recommendation for or against bariatric surgery in an individual patient with T2DM. It is worth to note that both groups displayed similar poor glycaemic control at baseline. There was a trend towards greater usage of insulin treatment within the bariatric surgery group. However, this was not significant. In comparison to published meta-analyses and in comparison to the GBSR, the patients from the bariatric surgery group in this analysis were older (GBSR: mean age: 40.7 years; Meta-analysis: 38.97 years; DPV-registry: 54.74 years) [8, 24]. The reasons for these observations may be that in the DPV registry, patients are included based on their diabetes manifestation, and not on the basis of elevated body weight; and the mean age at diabetes diagnosis is above 50 years [28]. Despite patients from the bariatric surgery group in DPV being substantially younger than patients without bariatric procedure (table 1), they had
longer diabetes duration. Therefore, this would suggest that diabetologists delay recommending bariatric surgery in patients with obesity and concomitant diabetes. The most frequently performed bariatric procedure in our database of patients with T2DM was sleeve gastrectomy, followed by Roux-en-Y gastric bypass and adjustable gastric banding. Higher diabetes remission rates and improvements in cardiovascular risk factors occurs after sleeve gastrectomy and Roux-en-Y gastric bypass as compared to adjustable gastric banding or other procedures [20, 29]. These data correlate well with the “German Bariatric Surgery Registry (GBSR)” and data from Europe, where Roux-en-Y gastric bypass and sleeve gastrectomy represent the most frequently performed bariatric procedures in general (GBSR: 83.4%; Europe: 89%) [7, 24, 30]. In this analysis, only 29 patients (15.8%) could be evaluated before and after a bariatric procedure. A possible explanation of this small number in the large DPV database may be that many of the patients had encountered a diabetes remission and didn’t have further regular diabetes checks and thus were lost to documentation in the registry. In the subgroup, after bariatric surgery a significant and clinically relevant reduction in median BMI from 45.23 to 38.00 kg/m² (-7.23kg/m²) was observed. Of note, this is less than reported in randomized controlled and other observational trials. In the meta-analysis by Chang et al. [31], the mean BMI reduction after 2 years was 13.23 kg/m² in RCT’s and 11.8 kg/m² in observational trials. A population-based cohort study from the UK in patients with T2DM only showed a BMI reduction of -7.8 kg/m² for adjustable gastric banding, -13.0 kg/m² for Roux-en-Y gastric bypass and -11.5 kg/m² for sleeve gastrectomy after 2 years. The reasons for these discrepancies remain speculative, especially because the pre-surgery BMI was similar (45.23 in the DPV-registry vs. 45.62 in the meta-analysis vs. 45.90 kg/m² in the UK cohort study). Possible explanations may be reporting bias, or
small sample size, which is due to the mode of evaluation. We found a significant decrease in HbA1c after bariatric procedures of -1.0%. Again, this was less than reported in other studies. In the meta-analysis of randomised-controlled trials from Muller-Stich et al. [17], the authors found a mean reduction of -1.4%, Schauer et al. [18] found a reduction of -2.5% and in an observational trial from the UK, after two years a reduction of -1.3% for adjustable gastric banding, -1.6% for gastric bypass and -0.9% for sleeve gastrectomy were reported [29]. With a mean HbA1c after bariatric procedure of 6.98%, the majority of patients still fulfilled the criteria for the diagnosis of T2DM (HbA1c > 6.5%), indicating significant improvement in glycaemic control. However, the majority of patients did not display “diabetes remission” based on this parameter as they were still taking anti-diabetic medication. There was a trend for fewer patients needing anti-diabetic medication after surgery, but this did not reach statistical significance. It may be that the patients had encountered a diabetes remission and didn’t have further regular diabetes checks and thus were lost to documentation in the registry. Therefore, these data must be considered with caution, since we analysed only a small sample size, and bigger observational and randomized trials indicate a diabetes “remission” in up to 80% obese patients after bariatric surgery [14, 17, 18, 25, 29, 32].

This study has several limitations but also strengths. First, the follow-up rate for the patients after bariatric surgery was low. Second, in the DPV-registry the data may be incompletely ascertained. However, the strength of this study is the use of data from a large representative nationwide diabetes patient care database in Germany and Austria. Therefore, the results may more accurately reflect current trends in the lack of uptake by diabetologists of bariatric surgery in daily practice than results from randomized clinical trials. Due to small sample size, however, the reported results of
reduced efficacy of bariatric surgery in normalisation of glycaemia in patients with T2DM, may not reflect real performance of this intervention in real life.

In conclusion, the proportion of T2DM patients with obesity who are referred for bariatric surgery in Germany and Austria by diabetologists is very small. Importantly, the BMI and not the metabolic or glycaemic control seem to represent the major selector for recommendation of bariatric surgery to patients with T2DM despite efficacy data showing favourable clinical and metabolic outcomes. In this analysis of “real life registry data”, the effects of BMI, glycaemic control and diabetes remission after bariatric procedures are not as favourable as in other published randomised controlled and observational trials or meta-analyses, and may simply represent a very small sample size. These observations would suggest the need to shift the focus away from BMI as a selection criteria, and move towards enhanced glycaemic control with improvement and/or remission of T2DM when counselling obese patients with T2DM. Furthermore, this may include the option of bariatric surgery based on metabolic control earlier in the course of T2DM.

Blinded Conflict of Interest Disclosure Statement:

The authors declare that they have no conflict of interest.

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K. L. has nothing to disclose.
N. P. has nothing to disclose.
J. B. has nothing to disclose.
A. S. has nothing to disclose.
M. A. has nothing to disclose.
R. W. has nothing to disclose.
F. G. has nothing to disclose.
D. K. has nothing to disclose.
E. B. has nothing to disclose.
J. S. has nothing to disclose.
R. W. H. has nothing to disclose.

References:


Figure Legend:

Figure 1:
Effect of bariatric procedures on BMI and HbA1c in patients with T2DM. A. Median with upper and lower quartile for BMI before bariatric procedure (Index Period 1: –24 to 0 months before bariatric procedure) and after bariatric procedure (Index Period 2: 0 to +24 months after bariatric procedure). *** p < 0.001, Index Period 1 vs. 2. n = 24. 
B. Median with upper and lower quartile for HbA1c before bariatric procedure (Index Period 1) and after bariatric procedure (Index Period 2). ** p < 0.01, Index Period 1 vs. 2. n = 21.

Figure 2:
Effect of bariatric procedures on insulin dose in insulin treated patients with type 2 diabetes mellitus. Median with upper and lower quartile for insulin dose before bariatric procedure (Index Period 1: –24 to 0 months before bariatric procedure) and after bariatric procedure (Index Period 2: 0 to +24 months after bariatric procedure). ** p < 0.01, Index Period 1 vs. 2. n = 12.
Table 1: Baseline clinical characteristic of study population – patients with bariatric procedure vs no bariatric procedure

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Bariatric Procedure</th>
<th>No Bariatric Procedure</th>
<th>p – value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 2 diabetes mellitus n = 277,862</td>
<td>n = 183 (0.07%)</td>
<td>n = 277,679 (99.93%)</td>
<td></td>
</tr>
<tr>
<td>Female sex – [%]</td>
<td>61.20</td>
<td>47.70</td>
<td>p &lt; 0.005</td>
</tr>
<tr>
<td>Age [years], median (Q1;Q3)</td>
<td>54.74 (47.40; 61.61)</td>
<td>70.04 (60.36; 77.58)</td>
<td>p &lt; 0.0001</td>
</tr>
<tr>
<td>Diabetes duration [years], median (Q1;Q3)</td>
<td>11.21 (7.15; 17.93)</td>
<td>8.36 (2.94; 14.91)</td>
<td>p &lt; 0.0001</td>
</tr>
<tr>
<td>Body weight – [kg], median (Q1;Q3)</td>
<td>120.90 (100.25; 140.00)</td>
<td>84.75 (73.40; 98.00)</td>
<td>p &lt; 0.0001</td>
</tr>
<tr>
<td>BMI – [kg/m²], median (Q1;Q3)</td>
<td>41.91 (36.42; 47.65)</td>
<td>29.69 (26.17; 34.02)</td>
<td>p &lt; 0.0001</td>
</tr>
<tr>
<td>BMI [kg/m²], mean</td>
<td>40.20</td>
<td>30.61</td>
<td>p &lt; 0.0001*</td>
</tr>
<tr>
<td>HbA1c [%], mean</td>
<td>7.25</td>
<td>7.56</td>
<td>n.s. p &lt; 0.05*</td>
</tr>
<tr>
<td>Insulin therapy – %</td>
<td>52.79</td>
<td>50.08</td>
<td>n.s. (p = 0.5)*</td>
</tr>
<tr>
<td>Insulin dose/kg*d, mean</td>
<td>0.56</td>
<td>0.58</td>
<td>n.s. (p = 0.7)*</td>
</tr>
<tr>
<td>Dyslipidemia – [%]</td>
<td>56.47</td>
<td>60.61</td>
<td>n.s. (p = 0.3)*</td>
</tr>
<tr>
<td>Treatment with lipid lowering drugs – [%]</td>
<td>30.03</td>
<td>24.80</td>
<td>n.s. (p = 0.1)*</td>
</tr>
<tr>
<td>Hypertension – [%]</td>
<td>71.26</td>
<td>63.42</td>
<td>p = 0.03*</td>
</tr>
<tr>
<td>Treatment with antihypertensive drugs – [%]</td>
<td>63.70</td>
<td>49.82</td>
<td>p = 0.0002*</td>
</tr>
<tr>
<td>Microalbuminuria – [%]</td>
<td>12.27</td>
<td>17.43</td>
<td>n.s. (p = 0.08)*</td>
</tr>
<tr>
<td>Diabetic retinopathy – [%]</td>
<td>5.21</td>
<td>7.23</td>
<td>n.s. (p = 0.26)*</td>
</tr>
<tr>
<td>Diabetic foot syndrome – [%]</td>
<td>9.44</td>
<td>5.55</td>
<td>p = 0.02*</td>
</tr>
<tr>
<td>Myocardial infarction – [%]</td>
<td>5.47</td>
<td>7.92</td>
<td>n.s. (p = 0.28)*</td>
</tr>
<tr>
<td>Cerebral apoplexy – [%]</td>
<td>7.05</td>
<td>6.34</td>
<td>n.s. (p = 0.75)*</td>
</tr>
</tbody>
</table>

Data given as n (%), least square means or median with lower and upper quartile (Q1; Q3). P-values are given for the comparison between type 2 diabetes mellitus patients with and without bariatric surgery. * least square means with adjusted p-values with adjustment for age, sex, and diabetes duration.
Table 2: Frequencies of bariatric surgery procedures

<table>
<thead>
<tr>
<th>Method</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleeve gastrectomy</td>
<td>n = 63 (34.4%)</td>
</tr>
<tr>
<td>Roux-en-Y gastric bypass</td>
<td>n = 61 (33.3%)</td>
</tr>
<tr>
<td>Gastric band</td>
<td>n = 39 (21.3%)</td>
</tr>
<tr>
<td>Not otherwise specified</td>
<td>n = 7 (3.8%)</td>
</tr>
<tr>
<td>Gastric balloon</td>
<td>n = 6 (3.3%)</td>
</tr>
<tr>
<td>Duodenal-jejunal-bypass-liner</td>
<td>n = 5 (2.7%)</td>
</tr>
<tr>
<td>Biliopancreatic diversion with duodenal switch</td>
<td>n = 1 (0.6%)</td>
</tr>
<tr>
<td>Gastric pacing</td>
<td>n = 1 (0.6%)</td>
</tr>
</tbody>
</table>

Values are given as n (%).
Table 3: BMI, HbA1c and use of medication pre- and post-bariatric procedure.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Index Period 1 (Pre-)</th>
<th>Index period 2 (Post-)</th>
<th>p – values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female sex – [%]</td>
<td>55.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age [year], median (Q1;Q3)</td>
<td>50.84 (46.12; 56.95)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes duration [year], median (Q1;Q3)</td>
<td>10.32 (4.58; 13.64)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body weight – [kg], median (Q1;Q3) (n = 25)</td>
<td>130.00 (110.70; 152.90)</td>
<td>105.00 (91.30; 119.40)</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>BMI [kg/m²], median (Q1;Q3) (n = 22)</td>
<td>45.23 (40.33; 51.72)</td>
<td>38.00 (31.81; 44.15)</td>
<td>p = 0.0004</td>
</tr>
<tr>
<td>HbA1c [%], median (Q1;Q3) (n = 20)</td>
<td>7.98 (7.27; 9.03)</td>
<td>6.98 (5.70; 7.70)</td>
<td>p = 0.0032</td>
</tr>
<tr>
<td>Proportion Insulin therapy – [%]</td>
<td>62.07</td>
<td>44.83</td>
<td>n.s. (p = 0.1)</td>
</tr>
<tr>
<td>Insulin therapy plus OAD/GLP-1RA [%]</td>
<td>44.83</td>
<td>27.59</td>
<td>n.s. (p = 0.1)</td>
</tr>
<tr>
<td>Insulin therapy only – [%]</td>
<td>17.24</td>
<td>17.24</td>
<td>n.s. (p = 1.0)</td>
</tr>
<tr>
<td>Insulin dose/kg*d median (Q1;Q3)</td>
<td>0.44 (0.32; 0.90)</td>
<td>0.41 (0.18; 0.50)</td>
<td>p = 0.004</td>
</tr>
<tr>
<td>OAD/GLP-1RA only – [%]</td>
<td>10.34</td>
<td>10.34</td>
<td>n.s. (p = 1.0)</td>
</tr>
<tr>
<td>Lifestyle only – [%]</td>
<td>27.59</td>
<td>44.83</td>
<td>n.s. (p = 0.1)</td>
</tr>
<tr>
<td>Microalbuminuria – [%]</td>
<td>10.34</td>
<td>13.79</td>
<td>n.s. (p=0.56)</td>
</tr>
<tr>
<td>Diabetic retinopathy – [%]</td>
<td>10.34</td>
<td>3.45</td>
<td>n.s. (p=0.32)</td>
</tr>
<tr>
<td>Diabetic foot syndrome – [%]</td>
<td>13.79</td>
<td>13.79</td>
<td>n.s. (p = 0.1)</td>
</tr>
<tr>
<td>Myocardial infarction – [%]</td>
<td>3.45</td>
<td>3.45</td>
<td>n.s. (p = 0.1)</td>
</tr>
<tr>
<td>Cerebral apoplexy – [%]</td>
<td>0.00</td>
<td>0.00</td>
<td>n.s. (p = 0.1)</td>
</tr>
</tbody>
</table>

Index Period 1: –24 to 0 months before bariatric procedure
Index Period 2: 0 to +24 months after bariatric procedure
Data given as n (%), median with lower and upper quartile (Q1; Q3).
OAD: oral antidiabetic drugs; GLP-1RA: glucagon like peptide – 1 receptor agonists
Figure 1:

A

![Box plot of BMI (kg/m²) across index periods]

B

![Box plot of HbA1c (%) across index periods]

Figure 2:

![Box plot of insulin dose/kg'd across months]

**Note:**

- **A**: BMI (kg/m²) across index periods with a significant difference marked by ***.
- **B**: HbA1c (%) across index periods with a significant difference marked by **.
- **Figure 2**: Insulin dose/kg'd across months with a significant difference marked by **. 

**Units:**

- BMI: kg/m²
- HbA1c: %
- Insulin dose: kg'd

**Significance Levels:**

- ***: p < 0.001
- **: p < 0.01