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## *RESEARCH ARTICLE*

# BARIATRIC SURGERY FOR TYPE 2 DIABETES IN SAUDI ARABIA: A COMPREHENSIVE REVIEW

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## *Abstract*

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Saudi Arabia faces a burgeoning obesity epidemic, with a significant impact on the prevalence of Type 2 Diabetes Mellitus (T2DM). This comprehensive review examines the effectiveness of bariatric surgery as a pivotal treatment option for managing T2DM in the context of Saudi Arabia’s socioeconomic and health landscape. Our review highlights the profound impact of bariatric surgery procedures on weight loss and T2DM remission rates, demonstrating a significant advantage over conventional medical management. The review also delves into the socio-cultural factors influencing the obesity and T2DM epidemic in Saudi Arabia, the economic burden of these conditions, and the national strategies implemented to combat them. We further discuss the importance of a multidisciplinary approach to treatment, encompassing lifestyle and dietary modifications, psychological support, and post-operative care, to ensure the long-term success of bariatric interventions. Our findings suggest that bariatric surgery offers a viable and effective treatment modality for T2DM management in Saudi Arabia, underscoring the need for patient-specific treatment planning and the importance of comprehensive post-surgical care. Future research directions include evaluating the long-term outcomes of bariatric surgery and optimizing patient selection criteria to enhance treatment efficacy and patient quality of life.



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## Introduction:-

Obesity is a significant global health concern, characterized by an excessive accumulation of body fat that increases the risk for various diseases, such as diabetes, certain cancers, cardiovascular issues, and hypertension(1–3). The prevalence of obesity and overweight has surged in the Eastern Mediterranean region, including Saudi Arabia, due to lifestyle changes such as unhealthy dietary patterns and reduced physical activity (4–6). A recent comprehensive survey conducted across all regions of Saudi Arabia revealed a 24.7% prevalence of obesity (7).This trend is alarming, given the associated long-term health risks, especially among children and adolescents (8,9).

Currently, the global prevalence of overweight or obesity affects 38% of the population, a figure that has significantly risen over the past four decades(10,11). In Saudi Arabia, the prevalence of obesity among adults stands at 36%, with a notable difference between genders (women 21%; men 12%)(11)v. The country faces a substantial economic impact from obesity-related conditions, with costs directly attributed to these conditions ($3.8 billion) representing a significant portion (4.3%) of the country’s total health expenditures in 2019 (12). Furthermore, the

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estimated costs related to absenteeism and presenteeism due to overweight and obesity amount to $15.5 billion, equivalent to 0.9% of the country's gross domestic product (12). A recent analysis highlighted that a 15% weight loss could lead to substantial cost savings, particularly in reducing obesity-related complications such as type 2 diabetes, dyslipidemia, and hypertension (13).

The prevalence of diabetes in Saudi Arabia has shown a concerning increase over the years, according to data from the International Diabetes Federation(14–17). By 2021, the number of individuals affected reached 4,274.1 thousand, with projections suggesting a continued rise. By 2030 and 2045, estimates indicate that the number of individuals with diabetes will climb to 5,631.0 and 7,537.3 thousand, respectively. Moreover, the age-adjusted comparative prevalence of diabetes has fluctuated noticeably, with a significant portion of the population affected. It stood at 18.7% in 2021, then increased to 20.4% by 2030 and 21.4% by 2045, highlighting the persistent challenge of diabetes within the Saudi Arabian population and the urgent need for effective strategies in prevention, management, and treatment of the disease within the country(17,18).

In response to the obesity epidemic, Saudi Arabia has launched strategic measures under its "Vision 2030 (Quality of Life Program)", aimed at reducing obesity by 3% and diabetes by 10%. Other obesity-related strategies in Saudi Arabia include the (a) "Obesity Control and Prevention Strategy," which falls under the Public Health Authority, cited as SCDC 2019, (b) the Ministry of Health oversees several strategies: "Obesity Control Program Strategy" (MOH 2014d), "Healthy Food Strategy" (SFDA 2018a), "Diet and Physical Activity Strategy" (MOH 2014a), "Saudi Arabia National Strategy for Prevention of noncommunicable diseases" (MOH 2014b), and "National Executive Plan for Diabetes Control" (MOH 2014c), and (c) "National Strategy for Prevention of Cardiovascular Disease", referenced as MOH 2010.These include calorie labeling on menus, taxes on sugary beverages, promotion of healthier diets, increased physical activity opportunities, and reforms in food product composition. Additionally, significant investments, such as allocating 500 million riyals towards obesity prevention and management, underscore the country's commitment to tackling these health issues. Despite these efforts and the progress in diabetes management, achieving optimal control remains challenging for many (19).

Amidst these challenges, diabetes management has become a focal point due to its close association with obesity. The risk of developing T2DM is elevated by more than six-fold in those with morbid obesity (20). The interplay between obesity and insulin resistance underscores the importance of weight reduction through lifestyle interventions, pharmacotherapy, or bariatric surgery as a pivotal strategy for managing T2DM in obese individuals.

The co-occurrence of obesity and T2DM presents a substantial public health dilemma, straining healthcare systems and impacting the well-being of those affected. Given the strong correlation between obesity and T2DM onset, bariatric surgery emerges as a pivotal intervention. Bariatric surgery has emerged as an effective approach for managing obesity and its associated health conditions, offering significant weight loss and long-term improvements in obesity-related conditions(21–26). Moreover, bariatric surgery emerges as a highly effective treatment for obesity and its comorbid conditions. The Roux-en Y Gastric Bypass (RYGB) and Laparoscopic Sleeve Gastrectomy (LSG) stand out as two of the most performed bariatric procedures, showing a persistent and superior effect in inducing T2DM remission compared to medical management. Notably, the long-term benefits of bariatric surgery, as demonstrated in the recent ARMMS-T2D study (27), include significant reductions in HbA1C levels and higher diabetes remission rates, highlighting the procedure's effectiveness in improving glycemic control and achieving diabetes remission over medical/lifestyle interventions (25). The evolution of bariatric surgery, particularly the growing preference for the LSG in Saudi Arabia(28), reflects a shift towards minimally invasive procedures that promise sustainable weight management and improved health outcomes(29,30).

By facilitating significant and enduring weight loss, bariatric procedures not only tackle obesity but also markedly reduce the risk of T2DM development or enhance glycemic control in individuals with existing diabetes. This review aims to comprehensively evaluate the efficacy of bariatric surgery as a therapeutic approach for T2DM in the obese population of Saudi Arabia. It endeavors to scrutinize the country's current landscape of bariatric surgery, evaluate its impact on diabetes remission and metabolic well-being, and pinpoint research gaps to propose avenues for future investigations. Through this analysis, the review aims to establish a solid groundwork for healthcare professionals, policymakers, and patients to grasp the potential of bariatric surgery in addressing the intertwined challenges of obesity and T2DM in Saudi Arabia.

## Literature Search:-

We conducted a literature review by searching databases such as PubMed, Google Scholar, and Web of Science through 2024. We aimed to capture a broad spectrum of research, covering both observational and experimental studies relevant to our investigation. The search strategy was designed around medical subject headings (MeSH) keywords such as “Bariatric surgery,” “Metabolic Surgery,” “Type 2 Diabetes Mellitus,” “Outcome,” and “Remission.”We used these terms singly and in various combinations, adhering to MeSH guidelines to ensure the comprehensiveness of our search. Our primary focus was on original research articles, including systematic reviews and meta-analyses, to gather robust evidence. However, we intentionally excluded case reports and case series to maintain the focus on studies providing a higher level of evidence.

**Bariatric Surgery and T2DM**

**Rationale**

Given the escalating prevalence of obesity and T2DM in Saudi Arabia, there is a pressing need for effective treatments that go beyond conventional medical management. Research has highlighted that factors like physical inactivity, exacerbated by cultural barriers, particularly among Saudi females, significantly contribute to this health crisis (31). Despite advances in diabetes care, achieving and maintaining optimal glycemic control remains a formidable challenge for many, underscoring the limitations of current pharmacological and lifestyle interventions (19,32).

Bariatric surgery emerges as a beacon of hope, as evidenced by a meta-analysis(33) and the ARMMS-T2D study(27), demonstrating the surgery’s superiority in inducing T2DM remission and achieving long-term glycemic control. In the meta-analysis, remission rates were significantly higher in surgical patients (52.5%) than those under medical management (3.5%) two years post-surgery. The RYGB procedure substantially improved HbA1C, fasting blood glucose, and lipid levels. Even after five years, the remission rate remained markedly elevated in surgery patients (27.5%) compared to non-surgical patients (3.8%), underscoring the enduring positive impact. The ARMMS-T2D 2024 study, which amalgamated data from four US single-center randomized trials involving 262 participants and a median follow-up of 11 years, demonstrated that bariatric surgery led to substantial decreases in HbA1C levels at 7 and 12 years when contrasted with medical/lifestyle management. Additionally, the surgery group required fewer antidiabetes medications, highlighting the superior glycemic control achieved through bariatric surgery over an extended period. Moreover, diabetes remission rates were consistently higher in the bariatric surgery cohort at both time points. While post-surgery adverse events such as anemia, fractures, and gastrointestinal issues were noted, major cardiovascular events did not show significant differences between the groups. This study underscores the long-term advantages of bariatric surgery in enhancing glycemic control and achieving diabetes remission when compared to medical/lifestyle interventions. These findings not only highlight the effectiveness of surgical interventions but also the necessity for broader access to bariatric surgery within populations grappling with the dual burden of obesity and T2DM, such as in Saudi Arabia.

**Eligibility and Limitations for Bariatric Surgery**

The criteria for bariatric surgery have evolved significantly since the National Institutes of Health (NIH) Consensus Development Panel first established guidelines for the surgical management of severe obesity in 1991 (34). The second Diabetes Surgery Summit (DSS-II) in 2017 marked a pivotal shift, advocating for the expansion of bariatric surgery access to include individuals with lower BMI, varied ethnic backgrounds, and those not achieving glycemic control through conventional means (35). This inclusive approach has received endorsement from over 45 international medical and scientific organizations, signaling a broad consensus on the value of bariatric surgery beyond traditional weight loss metrics.

In a significant update in 2022, the American Society of Metabolic and Bariatric Surgery (ASMBS) and the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) further refined the indications for bariatric surgery (36). Now, eligible candidates include adults with a BMI ≥35 kg/m$^2$regardless of comorbidity status, highlighting bariatric surgery’s efficacy in significant weight loss and mitigating obesity-related comorbidities for those classified with class II or higher obesity (37–41). Additionally, adults with a BMI of 30.0 to 34.9 kg/m$^2$and diagnosed with type 2 diabetes are recognized as suitable candidates, acknowledging bariatric surgery as an effective diabetes management strategy for those who do not benefit from non-surgical interventions. This is supported by many retrospective and prospective studies demonstrating lasting weight loss and improved diabetes control (35,42–46). Furthermore, the guidelines extend to adults within the same BMI range who are unable to achieve meaningful weight loss or comorbidity improvement through conventional methods, affirming the metabolic benefits of bariatric procedures for individuals with class I obesity (47).For those with diabetes and a BMI of 30 to 34.9 kg/m², bariatric and metabolic surgeries are considered safe and effective treatments, particularly for patients struggling with uncontrolled hyperglycemia despite optimal medical management (48). The process leading to surgery often involves mandatory lifestyle modifications, showcasing patient commitment. However, any preoperative weight loss that might adjust a patient's BMI below the surgical threshold does not disqualify them; the initial BMI at program entry is typically the benchmark, acknowledging obesity as a chronic condition where temporary weight loss seldom addresses long-term comorbidities or is sustained(49,50).

Bariatric surgery's scope extends beyond glycemic and lipid management to include cardiovascular risk reduction, with eligibility not solely determined by BMI (51). Contraindications exist, covering various medical and psychiatric conditions that may compromise surgery safety or its outcomes. Despite these, no absolute age limit is imposed, with patient fragility rather than chronological age being the determining factor for surgery viability (52,53). The recommendation for bariatric surgery in individuals under 18 underscores the procedure's potential to address severe obesity cases early, provided it is conducted within high-quality, specialized care settings (54,55). Furthermore, bariatric surgery is an effective option for managing clinically severe obesity in patients requiring other specialized surgeries like joint arthroplasty, abdominal wall hernia repair, or organ transplantation (36). These guidelines underscore bariatric surgery as a multifaceted intervention for obesity and its associated conditions, reflecting a nuanced understanding of its benefits and broadening eligibility criteria to maximize patient outcomes.

**ASMBS Endorsed Proceduresand Their Rationale**

**Mechanism**

Bariatric surgical procedures influence weight loss through three primary mechanisms: malabsorption, restriction, and neurohormonal changes that modulate hunger and energy balance, and some integrate restrictive and malabsorptive components (56–58). Restrictive methods, such as Vertical Banded Gastroplasty (VBG) and Laparoscopic Adjustable Gastric Banding (LAGB), limit caloric intake by reducing stomach capacity, but newer techniques like SG offer enhanced success through additional hormonal effects on appetite control. While intragastric balloon placement and aspiration therapy also limit intake, they tend to produce more gradual weight loss and have higher relapse rates. Malabsorptive surgeries, including Jejunoileal Bypass (JIB) and Biliopancreatic Diversion (BPD), alter the small intestine's length to impair nutrient absorption, effectively inducing weight loss but risking malnutrition and nutrient deficiencies. Conversely, RYGB, BPD with Duodenal Switch (BPD/DS), and Single-Anastomosis Duodenal Ileal Bypass with Sleeve Gastrectomy (SADI-S) merge restrictive and malabsorptive aspects.

**ASMBS Endorsed Procedures**

The American Society of Metabolic and Bariatric Surgery (ASMBS) endorses a variety of bariatric procedures, with 2020 data showing SG and RYGB as the most performed surgeries in the United States, attributed to their proven effectiveness in achieving significant and lasting weight reduction(59). The RYGB is a key bariatric surgery that utilizes both restriction and malabsorption by creating a small gastric pouch and connecting it to the small intestine's Roux limb, effectively limiting intake and nutrient absorption (60,61). The procedure has a restrictive component due to the small pouch and a malabsorptive component due to the shortened intestinal absorption surface. The optimal length of the Roux limb and biliopancreatic limb for achieving the best balance between weight reduction and complications of malabsorption is controversial (62–64). The procedure has been shown to be better than purely restrictive procedures in long-term weight reduction (65). The RYGB also affects hormones such as ghrelin, glucagon-like peptide-1 (GLP-1), and cholecystokinin (CCK), which may contribute to the loss of appetite and anorectic state in post-RYGB patients (66–68), with patients typically experiencing a loss of around 70% of excess weight within two years(69).

Conversely, the SG has risen to prominence for its straightforward approach, becoming the most-performed bariatric procedure since 2016, making up 58% of all bariatric surgeries in the U.S. in 2020 (59,70). This procedure involves removing a portion of the stomach to reduce its size, limiting how much can be eaten, and triggering hormonal changes that suppress appetite and improve metabolic functions. Despite being primarily restrictive, SG also influences gastric motility, potentially impacting weight loss outcomes (71,72). SG transforms the stomach into a high-pressure organ with sphincters at both ends, leading to more frequent leaks than RYGB and increased leak management challenges(73). Additionally, SG is associated with a higher incidence of gastroesophageal reflux disease due to its elevated pressure nature (74). The weight loss mechanism of SG extends beyond restriction, with hormonal changes playing a significant role in reducing hunger and improving glycemic control. Ghrelin levels decrease, while GLP-1 and PYY levels increase post-SG, contributing to reduced appetite and improved insulin sensitivity (39,75). After two years, SG typically results in an expected excess weight loss of around 60% or approximately 30% total body weight loss (76,77). The choice between RYGB and SG should be tailored to the individual's health needs, lifestyle, and weight loss goals, considering the distinct benefits and limitations of each procedure.

The ASMBS endorses some other procedures, including the Biliopancreatic Diversion with Duodenal Switch (BPD/DS), Single-Anastomosis Duodenoileal Bypass with Sleeve Gastrectomy (SADI-S), Intragastric Balloon (IGB), and One-Anastomosis Gastric Bypass (OAGB), each offering unique mechanisms for weight loss. Each offers unique mechanisms to facilitate significant weight loss and improve metabolic health.

BPD/DS integrates both restrictive and malabsorptive approaches, altering hormone levels such as ghrelin to decrease appetite and sustain weight reduction. Patients can expect an impressive 70 to 80% excess weight loss, translating to about 40% total body weight loss within two years (69,78,79). Conversely, the IGB is a less invasive option that enhances satiety, acting as a preliminary step to more definitive surgical procedures (80,81). It has proven effective, with individuals maintaining a substantial portion of their initial weight loss even six months after removal (82,83). OAGB simplifies the bariatric process by blending restriction and malabsorption for weight loss (75,84).Studies have shown that the OAGB can lead to substantial weight loss outcomes, with excess weight loss percentages ranging between 68.6% to 85% over a five-year follow-up period, positioning it as an equally effective or sometimes superior option compared to the RYGB and the SG (85–88). One of the standout features of OAGB is its significant impact on metabolic health, particularly in the context of T2DM management. Patients undergoing OAGB have reported lower glycated hemoglobin levels post-surgery compared to those who underwent LSG, indicating a marked improvement in glycemic control and, in some cases, remission of T2DM. Despite these positive outcomes, OAGB carries risks of malabsorption-related complications and alkaline bile reflux, which may necessitate conversion to RYGB in severe cases (85,89–91)SADI-S, a simplification of BPD/DS with a single anastomosis, maintains weight loss through a mix of restrictive, malabsorptive, and hormonal adjustments (92). Its weight loss efficacy rivals that of traditional surgeries, offering about 85% excess weight loss, equivalent to approximately 40% of total body weight in two years (93). While SADI-S has shown comparable weight loss outcomes to RYGB, SG, and BPD/DS in nonrandomized studies, it has advantages such as fewer anastomotic complications (94–96). However, SADI-S is linked to a higher risk of chronic diarrhea, especially with a 300 cm common channel length, leading to concerns about malnutrition rates with shorter common channels, a factor that merits further investigation for optimal surgical outcomes (94, 95, 96-98).

**Achieving T2DM Remission and Weight Loss through Bariatric Surgery**

**Underlying Mechanisms and Predictors**

The remission of T2DM post-bariatric surgery involves a complex interplay of mechanisms, some of which are still being unraveled. Caloric restriction, rather than significant weight loss alone, has been implicated in the immediate post-operative reduction in plasma glucose levels, although the precise mechanism is yet to be fully understood (97). The key to the remission process is the intestinal hormonal changes that lead to the formulation of the hindgut and foregut hypotheses. The hindgut hypothesis posits that accelerated nutrient delivery to the distal intestine enhances the secretion of beneficial peptides like GLP-1 and peptide YY, thereby fostering B-cell proliferation and insulin production (98–100). The foregut hypothesis, in contrast, suggests that bypassing the proximal intestine diminishes the secretion of detrimental anti-incretin hormones, improving glucose metabolism (99). Additionally, post-surgery decreases in ghrelin and alterations in adipocyte-derived hormones such as leptin and adiponectin further contribute to the antidiabetic effects by modifying appetite and insulin sensitivity (101–105). Emerging research into adipocyte-derived exosomal microRNAs presents new insights into the metabolic changes following gastric bypass, linking them to improved insulin resistance (106).

The potential for T2DM remission post-surgery can often be predicted by evaluating various preoperative factors(107,108). The ABCD score, integrating aspects like BMI, C-peptide levels, duration of T2DM, and patient age, serves as a predictive tool for assessing the likelihood of surgical success in T2DM management (109). Notably, individuals with a shorter diabetes duration typically see greater benefits, attributed to the lesser extent of B-cell damage, whereas those with lower BMIs or longer disease histories might derive less advantage (110–112). C-peptide levels serve as markers of insulin production and beta-cell function, indicating the potential success of bariatric surgery in triggering T2DM remission (112). Although age alone may not directly predict surgical outcomes, it provides valuable insight, as older patients generally see less benefit from these procedures (113). A comparison between the ABCD score and the DiaRem score revealed that the former is more reliable and comprehensive than the latter (113). The DiaRem score lacks consideration for the duration of T2DM, a critical factor in predicting diabetes remission.

The DiaRem score's development, based on data from patients with a high mean BMI undergoing surgery regardless of diabetes status, underlines its comparative limitations.To enhance predictive accuracy, the Duke Group introduced a logistic regression model incorporating a broader demographic and a range of bariatric surgeries (114). Analysis of 602 patients undergoing surgeries like RYGB, SG, LAGB, and BPD/DS indicated a notably higher remission likelihood within one year, highlighting the significant role of surgery type in remission rates (114). This insight underscores the importance of considering the specific bariatric procedure in future predictive models and clinical decision-making tools.

Aminian et al. (115) further refined the approach with the Integrated Metabolic Surgery Score (IMSS), including factors such as diabetes duration, medication count, insulin use, and HbA1c levels. This model stratifies patients by diabetes severity, recommending RYGB for mild to moderate conditions and SG for more severe cases, prioritizing procedure simplicity where higher remission rates are less likely. This scoring system emphasizes personalized treatment planning, although it does not include the BPD/DS, a procedure known for its high remission efficacy, possibly due to its complexity and associated risks.

**Clinical and Biological Determinants**

Bariatric surgery's role in achieving T2DM remission is substantiated by diverse mechanisms and clinical trial data, although outcomes vary among patients. Key to understanding these variances is identifying predictors of glycemic response post-surgery. Research has centered on biological and clinical markers predictive of T2DM remission, underlining the importance of clear remission definitions for study comparability. Complete remission involves fasting plasma glucose levels below 100 mg/dl and/or HbA1c levels below 6% for at least one-year post-surgery without diabetes medications. Partial remission is marked by fasting plasma glucose levels below 126 mg/dl and/or HbA1c levels below 6.5%, again without the need for antidiabetic medication for at least a year (42,116). Prolonged complete T2DM remission lasting beyond five years may be considered akin to a cure in practical terms (116). Interestingly, the duration of T2DM remission post-surgery averages around 8.3 years with RYGB, but relapse occurs in 20-30% of individuals after roughly six years, underscoring the complex nature of long-term diabetes management post-surgery (117).

Current research indicates that preoperative BMI in the obese range does not reliably predict cardiometabolic advantages in terms of T2DM prevention, remission, cardiovascular disease incidence, and mortality (42). A recent meta-analysis investigating T2DM remission across various BMI categories demonstrated that baseline BMI (<35 and >35 kg/m$^2$) does not significantly impact the rates of diabetes remission post-bariatric surgery (118). This finding suggests that preoperative BMI alone may not serve as a reliable predictor of metabolic improvement following surgery. Instead, the degree of weight loss post-operation is identified as a pivotal determinant in achieving T2DM remission, with patients who experience significant weight reduction showing notably higher remission rates, regardless of their initial BMI (117).

The International Diabetes Federation emphasizes a holistic approach to metabolic control, advocating for the management of all metabolic parameters, including glycemic control, hypertension, and dyslipidemia, rather than focusing solely on T2DM remission. This approach supports the integration of medications alongside surgery to enhance and maintain metabolic benefits over time.

Several factors have been consistently associated with lower T2DM remission rates and an increased likelihood of relapse, such as longer disease duration, the necessity of intensive insulin regimens before surgery, and poor glycemic control (118,119). Despite these challenges, individuals with significant preoperative metabolic issues might derive substantial benefits from metabolic surgery, potentially experiencing notable improvements in metabolic control even without full hyperglycemia remission. Consequently, prioritizing such patients for surgery could be advantageous, considering their elevated risks of morbidity and mortality.Conversely, factors like shorter T2DM duration (less than eight years), lower preoperative fasting blood sugar levels, and surgeries that involve intestinal diversion have been independently linked to higher remission rates and reduced relapse risks (118,119). Additionally, a smaller baseline waist circumference and lower visceral fat area before surgery are associated with better metabolic outcomes, highlighting the importance of early surgical intervention in suitable candidates (118,119).

However, this prioritization should not exclude patients with long-standing and poorly controlled diabetes, who may still see substantial and lasting improvements in blood sugar control post-surgery, even if complete remission is not attained. While short-term outcomes of bariatric surgery are promising, the long-term sustainability of diabetes remission poses a clinical challenge. Despite many patients experiencing long-term improvements in diabetes markers, a significant portion relapses, with studies indicating a nearly 50% relapse rate among those who initially achieved remission (120–123). A 15-year follow-up study observed a decline in diabetes remission rates over time, reinforcing the complexity of managing T2DM in the long term (124). This underscores the need for a comprehensive, individualized approach to bariatric surgery, considering both the potential for significant metabolic improvements and the challenges of maintaining these benefits over time(125).

Studies have shown that patients undergoing bariatric surgery experience a significant reduction in the need for oral antidiabetic medications and insulin, with up to an 87% decrease in oral medication use and a 79% reduction in insulin dependency post-surgery (121,126,127). Notably, gastric bypass has been associated with a greater reduction in diabetes medication usage compared to SG (128). These surgical interventions also contribute to sustained glycemic control, leading to a lower incidence of diabetes-related complications over time and, consequently, a reduction in mortality rates. Current evidence highlights a significant decrease in microvascular [hazard ratio of 0.44] and macrovascular complications [hazard ratio of 0.68] among surgical patients compared to non-surgical controls, highlighting the long-term protective effects of bariatric surgery (124,129,130).

In terms of preventive medicine, bariatric surgery has shown promise in preventing the onset of diabetes, with a significant reduction in diabetes risk observed both 2 and 15 years post-surgery, according to the SOS study (124,131). This preventive aspect underscores bariatric surgery's role not only as a treatment modality but also as a preventative measure against diabetes and its associated complications.

However, achieving and maintaining weight loss and metabolic improvements post-surgery necessitates addressing disordered eating behaviors, such as emotional eating, which can undermine the effectiveness of dietary advice and surgical interventions (132). The importance of diet in post-surgical maintenance underscores the need for bariatric surgeons to assess and address patterns of disordered eating and psychiatric symptoms prior to surgery, tailoring pre- and post-operative care to enhance long-term success.

Bariatric surgery can also lead to nutritional deficiencies, impacting the absorption of micronutrients and medications, which underscores the necessity of lifelong dietary management and supplementation to mitigate potential health challenges (133). The recognition of these deficiencies, along with the management of post-operative eating disorders, is crucial for ensuring the comprehensive success of bariatric treatment.

**Evolving Landscape and Impact of Bariatric Surgery in Saudi Arabia**

The rising popularity of bariatric surgery in Saudi Arabia, with an estimated 15,000 procedures performed annually, reflects its growing recognition as an effective intervention for weight loss and metabolic control (134,135). A 2023 survey with 388 participants aged 18 and above revealed significant awareness of obesity as a health concern (85.8%) and its linkage to metabolic complications like T2DM and hypertension (80.90%) (134). Notably, a majority (67.3%) understood obesity's impact on insulin sensitivity, supported by Alharbi et al.'s study, which found that 55.6% of 421 T2DM individuals were obese (136). Among these participants, 91.5% were aware of bariatric surgery, particularly sleeve gastrectomy, indicating its widespread acceptance. However, only 46.10% were aware of the eligibility criteria for such surgeries, suggesting a gap in comprehensive knowledge (134,137)

Awareness of potential surgical complications was also significant, with 70.1% acknowledging risks like internal bleeding (41%) and anemia (35.1%) as major concerns, consistent with findings by Alayaaf et al.(137). The study further demonstrated bariatric surgery's efficacy, with 37.6% of participants reporting positive outcomes, including substantial weight loss, reduced diabetes medication needs, and better glycemic control post-surgery. This finding underscores the procedure's impact on enhancing patient health and well-being. Interestingly, awareness and familiarity with bariatric surgery varied by gender and nationality, with females and Saudi nationals more likely to be familiar with sleeve gastrectomy in the same study. However, demographic factors like age, education, or income did not significantly influence awareness, highlighting the need for targeted health communication strategies.

Limited research in Saudi Arabia has explored the impact of bariatric surgeries on weight loss, glycemic control, and remission. Studies like those by Alnajjar et al. have documented significant improvements in HbA1c, fasting blood glucose, and BMI among post-surgical patients in one year, showcasing the procedure's profound benefits on metabolic health (138). As per ADA criteria, the complete remission rate in their study was 2.6 times higher than the partial remission rate in patients undergoing any form of bariatric surgery (138). This is consistent with other studies, showing a significant difference in complete remission rates compared to partial remission rates (139). Another study utilized the BAROS protocol post-bariatric surgery to assess outcomes in 346 patients who underwent sleeve vertical gastrectomy, Roux-en-Y gastric bypass, or pancreaticoduodenal switch with duodenal switch. Results indicated that bariatric surgery resulted in a significant weight reduction and improvement in obesity-related comorbidities. The participants' BMI decreased from 43.77 ± 6.46 to 29.66 ± 6.88 kg/m$^2$ pre- and post-intervention [transitioned individuals from morbid obesity to overweight within one-year post-surgery according to the WHO BMI classification] (140). Moreover, both diastolic and systolic blood pressure reduced from 97.39 ± 12.41 to 85.31 ± 9.29 mm Hg and 156.89 ± 23.12 to 122.89 ± 15.3 mm Hg, respectively, demonstrating the surgery's effectiveness in lowering hypertension levels. Gastric bypass has been shown to result in significant remission rates for diabetes (95%), dyslipidemia (80%), hypertension (81%), and sleep apnea (95%). Similarly, sleeve gastrectomy has demonstrated reductions in diabetes (86%), hypertension (82%), dyslipidemia (83%), and sleep apnea (91%).In 2018, Ahmed et al. (138) observed significant weight loss in patients with a BMI over 40 kg/m^2 within 12 months following LSG, noting a 25% reduction in weight (141). Further analysis revealed notable improvements in BMI and glycemic control one-year post-LSG (142). Another research (143) evaluated LSG's effects on 102 patients with a BMI of 30 kg/m^2 or more. This study recorded substantial enhancements in HbA1c levels and BMI after an average follow-up of 10 months, with 84.3% of patients achieving a BMI under 40 kg/m^2 and a collective 30% BMI reduction. Diabetic and prediabetic patients experienced weight losses of 28.3% and 32.45%, respectively, accompanied by a 26.4% decrease in HbA1c levels. This emphasizes the role of bariatric surgery in moving patients from morbid obesity to a lower-risk category, thus reducing their risk for obesity-related complications.

A recent meta-analysis focusing on the Saudi population (144) compared the outcomes of LSG and RYGB, the leading bariatric surgeries, in individuals with morbid obesity and T2DM. The study included data from 3 studies with 760 patients, **Table 1 and Figure 1**, and demonstrated both surgeries' effectiveness in reducing BMI (mean difference of 1.54; CI: 0.76–2.32) and improving glycemic control (mean difference of 0.30; CI: 0.07–0.54), marking a significant advancement in treating obesity and uncontrolled diabetes. Thus, the choice of surgery can be tailored to the patient's specific health profile and preferences. Moreover, these findings contribute to the evidence supporting bariatric surgery not just for weight loss but also as a critical component of diabetes management strategy in individuals with morbid obesity in the Saudi Arabian population.

Quality of life (QoL) assessments show that post-surgery, middle-aged individuals generally report improved scores across various domains (138). This reflects the trend that younger age correlates with improved quality of life post-surgery, and this may be attributed to older patients facing a higher risk of complications and mortality (145). Interestingly, the type of surgery performed influences QoL differently, with LSG scoring higher in physical aspects and bypass surgery in social domains. However, no significant overall difference was observed between the surgical procedures in terms of QoL, aligning with findings from a systematic review (146). Arishi et al. (2023) further confirmed these results, with participants reporting improved post-operative BAROS scores and a high rate of favorable outcomes (80.3%) based on the BAROS criteria. Sleeve gastrectomy was identified as the most commonly performed procedure, showcasing its prevalence and effectiveness in enhancing patient lives in Saudi Arabia (140).The impact of bariatric surgery on quality of life is a vital aspect of its overall benefits, with the evidence suggesting substantial improvements post-surgery. The varied impact on QoL between LSG and bypass surgeries highlights the importance of incorporating patient preferences and expected QoL outcomes into the decision-making process for bariatric surgery, ensuring that patients receive the most beneficial and suitable treatment for their condition.

**Analysis of Current Knowledge Gaps and Future Research Directions**

Upon reviewing the research landscape concerning the long-term effects of bariatric surgery on T2DM in Saudi Arabia, several notable research gaps emerge that necessitate further exploration. While current studies offer valuable insights into the effectiveness of bariatric surgery in inducing T2DM remission and enhancing metabolic outcomes, much of the data focuses on short to medium-term results. There is a clear absence of extended follow-up studies that monitor the sustainability of diabetes remission and the enduring impact of bariatric surgery on metabolic health within the Saudi population.

**Identified Research Gaps:**

Despite promising results in initiating T2DM remission, the long-term persistence of this remission remains inadequately characterized, particularly in the Saudi Arabian setting. Studies often lack extended post-surgery follow-ups, leaving a significant gap in understanding the lasting benefits.The comparative efficacy of various bariatric surgical techniques in the Saudi population is another underexplored area. Direct comparisons over an extended period are crucial for personalized patient care and optimizing surgical outcomes.While T2DM remission is pivotal, a comprehensive evaluation of bariatric surgery's effects on additional metabolic parameters like lipid profiles, blood pressure, and liver function tests over a prolonged duration is essential.The impact of cultural, dietary, and lifestyle factors specific to the Saudi population on the long-term consequences of bariatric surgery remains insufficiently investigated. These factors could significantly influence surgical success rates and post-surgery T2DM management.

**Future Research Directions**

Conducting longitudinal studies tracking patients over extended periods, ideally spanning a decade or more, is imperative to assess the enduring sustainability of T2DM remission and other metabolic outcomes post-bariatric surgery in Saudi Arabia.Future research should focus on direct comparisons between different bariatric surgical procedures to determine the most effective approaches for the Saudi population concerning T2DM remission and overall metabolic health improvement.Exploring integrated management approaches that combine bariatric surgery with lifestyle modifications, dietary adjustments, and pharmacological interventions could offer insights into optimizing long-term outcomes for post-surgery T2DM patients. Investigating adaptations in post-surgery care and lifestyle interventions tailored to the cultural and social context of the Saudi population could enhance the long-term success of bariatric surgery in managing T2DM. By addressing these research gaps, future studies can significantly enhance the effectiveness of bariatric surgery as a therapeutic option for T2DM in Saudi Arabia, ensuring that patients receive personalized and optimal care over an extended period.

## Conclusion:-

In conclusion, our comprehensive review underscores the significant role of bariatric surgery as an effective intervention for managing T2DM amidst the escalating obesity epidemic in Saudi Arabia. Our findings highlight the alarmingly high prevalence of obesity and T2DM in the region, attributing these conditions to lifestyle changes and urbanization that have led to decreased physical activity and unhealthy dietary habits. The review reveals that bariatric surgery, particularly the LSG and RYGB, not only facilitates substantial weight loss but also contributes to the remission of T2DM, showcasing superior outcomes compared to traditional medical management. This review further illustrates the importance of selecting the appropriate surgical procedure based on individual patient profiles, with a growing preference for the LSG in Saudi Arabia due to its minimally invasive nature and comparable efficacy. However, it also acknowledges the necessity of addressing the preoperative and post-operative challenges, including patient education, lifestyle modifications, and the management of potential nutritional deficiencies, to ensure the long-term success of bariatric surgery. We recommend that bariatric surgery should not be viewed in isolation but as part of a comprehensive, multidisciplinary approach to managing obesity and T2DM. This approach includes dietary advice, physical activity, psychological support, and medical management tailored to each patient's unique needs and circumstances. Such a holistic strategy is crucial for achieving optimal metabolic control, improving quality of life, and reducing the long-term health risks associated with obesity and T2DM. In light of this, bariatric surgery presents a promising option for individuals with obesity-related T2DM in Saudi Arabia, offering not just a treatment modality but a potential pathway to remission for many patients. Nonetheless, the successful implementation of bariatric surgery as a treatment option requires a concerted effort from healthcare providers, policymakers, and the community to foster an environment that supports patients throughout their journey toward recovery and health. As Saudi Arabia continues to combat the dual burden of obesity and T2DM, further research is imperative to explore the long-term outcomes of bariatric surgery and to refine the selection criteria for candidates. This will ensure that the benefits of bariatric surgery are maximized, thereby contributing to the overall enhancement of public health in the kingdom.

**Tables and Figures**

**Figure 1:-** Illustrates the changes in BMI and HbA1c levels across studies published in Saudi Arabiaover the past five years.

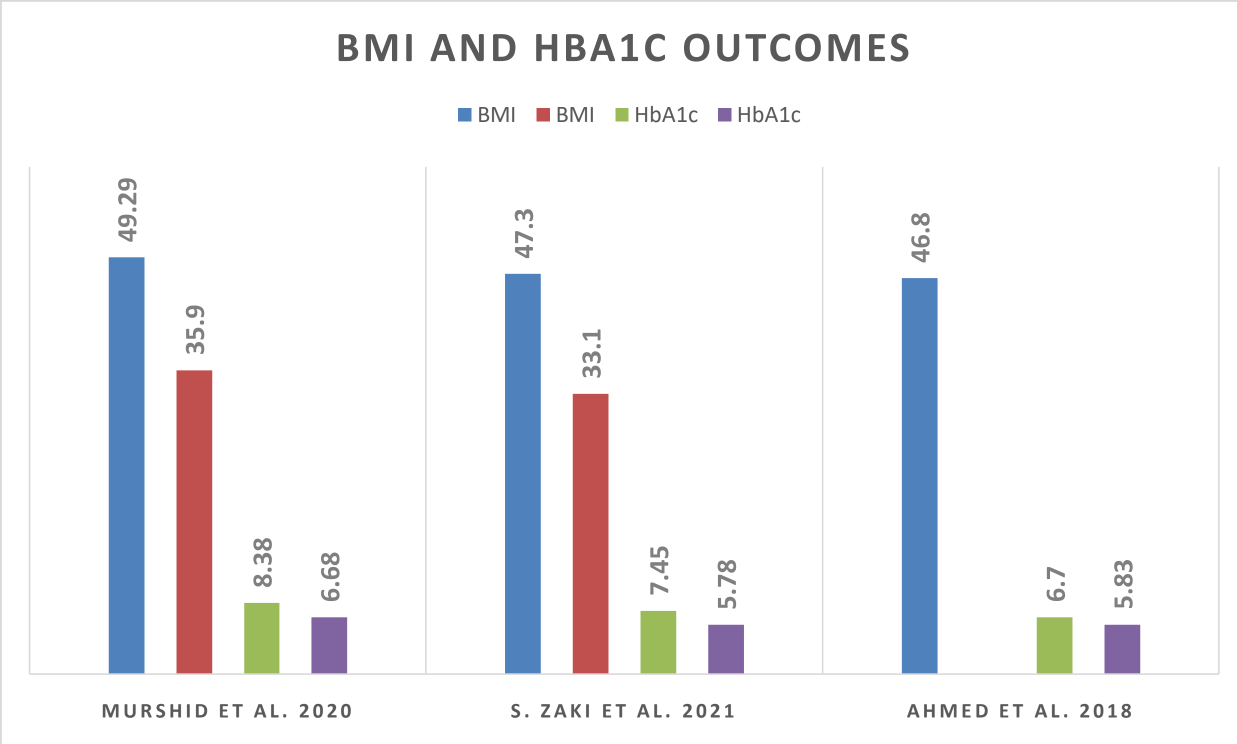


**Table 1:-** Summarizes the key characteristics of studies published in Saudi Arabia over the past five years.

| Study ID<br><br>Variable | Murshid et al. 2020(147) | S. Zaki et al. 2021(148) | Ahmed et al. 2018(149) |
|---|---|---|---|
| Study Location | King Fahad Hospital in AlmadinahAlmunawwarah, KSA | King Fahad Hospital in Al-Madinah Al-Munawwarah, KSA | King Abdulaziz Medical City in Riyadh, KSA |
| Study design | Analytical retrospective investigation | Cross-sectional study | Retrospective study |
| Study period | January 1, 2015 – July 31, 2019 | January 2017 – December 2019 | January 1, 2001 – March 31, 2017 |
| Study sample [Gender (n and %)] | 340 patients [M: 9 (22.0%); F: 32 (78%)] | 102 patients [M: 28 (27.5%); F: 74 (72.5%)] | 318 patients [M: 103 (32.4%); F: 215 (67.6%)] |
| Age | 47.54±10.791 | 41.6±12.2 | 34.7±11.7 |
| Inclusion criteria | Age >15 years, BMI ≥35 kg/m2, diagnosed with T2DM | Underwent LSG, BMI ≥30 kg/m2 and HbA1c ≥5.7% before the surgery | Patients with obesity class 1 or higher (BMI ≥ 30 kg/m2) |
| Intervention group | All underwent LSG | All underwent LSG | All underwent LSG or RYGB |
| Result | LSG is associated with reduced BMI and HbA1c | LSG positively impacts weight and HbA1c | LSG and RYGB are linked to HbA1c reduction, subsequently reducing BMI. |
| Baseline BMI (kg/m2) (M and SD) | Mean 49.29 | 47.3±7.73 | 46.8±7.7 |

| | | | |
|---|---|---|---|
| Postoperative BMI, last follow-up (kg/m2) | Mean after less than 1 month: 44.73, 1–3 months: 40.65, 4–6 months: 35.28, 7–9 months: 35.18, 10–12 months: 32.72, and after 1 year: 35.90 | 33.1 ± 6.72 | -* |
| Baseline HbA1c (%) | 8.38 | 7.45±1.66 | 6.7±2.1 |
| Postoperative HbA1c, last follow-up (%) | Mean after less than 1 month: 8.63, 1–3 months: 6.68, 4–6 months: 5.96, 7–9 months: 6.68, 10–12 months: 6.21, and after 1 year: 6.68 | 5.78 ± 0.92 | 5.83±0.9 |

Continuous data are presented as mean and standard deviation. M: Male, F: Female, BMI: Body mass index,LSG: Laparoscopic Sleeve Gastrectomy, RYGB: Roux-en-Y gastric bypass. *The study categorized patients based on their BMI reduction into three groups (0–9, 10–14, and >14 kg/m$^2$) postoperatively. It highlighted that greater reductions in BMI were associated with more significant improvements in HbA1c levels, especially among diabetic patients, suggesting that more substantial weight loss contributes to better glycemic control.

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